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NEW MEXICO TECH

SCIENCE • ENGINEERING • RESEARCH UNIVERSITY



Program and Course Catalog

2015-2016

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Accreditation

New Mexico Tech is accredited by the North Central Association of Colleges and Secondary Schools as a doctoral degree-granting university. Its credits are accepted by leading colleges and universities throughout the United States. It is approved by the Attorney General of the United States for the attendance of non-immigrant students, by the United States Department for Exchange Visitor Program P-I-1282, and by the Veteran's Approval Division of the Office of Military Affairs for attendance by students entitled to veteran's benefits.



HLC Contact Information:

New Mexico Tech is accredited by [The Higher Learning Commission](http://www.ncacihe.org/), which is part of the North Central Association of Colleges and Schools. <http://www.ncacihe.org/> (312) 263-0456.

NMT Contact Information:

New Mexico Tech 801 Leroy Place Socorro NM 87801 575-835-5434

The bachelor's programs in chemical engineering, civil engineering, electrical engineering, mechanical engineering, environmental engineering, materials engineering, mineral engineering and petroleum engineering are accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

The 'Bachelor of Science in Computer Science' program is accredited by the Computing Accreditation Commission (CAC) of ABET, <http://www.abet.org>.

New Mexico Tech is also a member of the American Society for Engineering Education.

Course Descriptions and Curricula

Course Descriptions

Course Numbers

Courses are arranged numerically by department or program. In general, courses numbered from 100 to 199 are intended primarily for first-year students (freshmen); 200 to 299 for second-year students (sophomores); 300 to 399 for third-year students (juniors); 400 to 499 for fourth-year students (seniors); and 500 to 599 for graduate students. Exceptions may be made with the approval of the major advisor and instructor. Graduate students may be allowed credit for courses numbered 300 and above.

Credit Hours

Following the course title, you will find the number of credit hours (cr) you will receive for completing the course. Credit hours are measured in class hours (cl hrs), lab hours (lab hrs), and recitation/discussion hours (recitation hr).

Credit hours for all courses, including synchronous and asynchronous distance delivery courses, are measured in class hours (cl hrs), lab hours (lab hrs), or recitation/discussion hours (recitation hrs).

"1 cl hr" and "1 recitation hr" correspond roughly to one hour spent in class each week during a standard 16-week semester and is equivalent to one (1) credit hour. "3 lab hrs" equals about three hours per week in the laboratory during a standard 16-week semester and is also equivalent to one (1) credit hour.

In addition to class and lab time, students can expect to spend about two to three hours of study and preparation for each credit hour of class. Most one-semester classes average three credit hours.

Summer courses and other compressed-format courses are required to meet the requirements stated above regardless of their shortened term.

Prerequisites and Corequisites

Some courses have prerequisites or courses you must successfully complete before enrolling in that course. Exceptions can be made with the instructor's approval. If you enroll in a course in which you do not have the prerequisites without the instructor's permission, you may be disenrolled.

Corequisites are courses taken during the same semester.

Prerequisites and corequisites are not determined by the student's individual catalog, but rather by the catalog in effect at the time that the course is offered.

Semester Offered

Not all courses are offered every semester. The first semester of a two-semester-sequence course (such as ACCT 201/202, ES 110/111, and EARTH 101/102) is usually offered in the fall semester. The second semester is usually offered in the spring semester. Courses that are offered only one semester ("Offered fall semesters") or alternate years ("Offered Spring Semesters and alternate years") are so noted. "Offered on demand" implies that the course is offered only when a sufficient number of students want to enroll in the course.

Description

The course description contains a short list of topics to be covered during the semester. This list is not meant to be exhaustive.

Cross-listing

Sometimes courses fulfill the requirements for two different degrees and are listed under both programs. In such cases, the course description will end with the cross-listing "(Same as BCS 283)."

Electives

Electives are courses taken in addition to the specific courses required by your major. Electives bring your credit hours up to the required number for graduation. Some majors allow students to choose many electives; others, few.

New Mexico Tech's community education classes (designated by the letter "C" in the course number) may not be used to fulfill the General Education Core Curriculum Requirements for a Bachelor of Science degree (listed on page 7). However, these classes may be used to fulfill elective credit for some programs.

Degree Requirements

In order to graduate, every student enrolled in a Bachelor of Science program must complete NM Tech's General Education Core Curriculum Requirements, which are listed on page 7. This core set of requirements contains courses in humanities, mathematics, and basic science or engineering.

Graduate students must also complete a set of general requirements (see page 7).

In addition, each program has its own set of courses you must complete to earn the degree, as well as the minimum number of credit hours needed to graduate.

Sample Curricula

Most programs provide sample curricula to help you set your schedule. While you will graduate at the end of four years if you follow the sample curriculum faithfully, *these curricula are meant to be guides only. Talk with your advisor to chart your individual curriculum and select electives to round out your degree program.*

New Mexico Common Course Numbering System (NMCCNS)

A common course numbering system has been devised by New Mexico colleges and universities in compliance with the New Mexico Post-Secondary Education Articulation Act. The purpose of the system is to assist New Mexico students who are transferring between institutions within the state. The system provides a neutral state wide course identifier for those courses that are similar in nature and considered to be equal in transfer. Students will find in the course description section of the catalog the state wide course identifier and the area of the General Education Common Core in brackets following the New Mexico Tech course for which the course can meet general education requirements. (See Page 6-7.)

General Education Core Curriculum Requirements

Requirements for a Bachelor of Science Degree

To fulfill the general education core curriculum requirements for the Bachelor of Science degree from New Mexico Tech, each student must complete the courses listed in this section. Where there are options, the student should consult with his or her appointed advisor.

Requirements for a Bachelor of General Studies Degree

The General Education Core Curriculum requirements for a Bachelor of General Studies are found on page 33-34 of the Program and Course Catalog.

Purpose of the General Education Core Curriculum Requirements

New Mexico Tech views its general education core curriculum requirements as the foundation for a broad and meaningful educational experience for all its undergraduates. The New Mexico Tech general education core curriculum requirements prepare students to communicate and reason well, evaluate and apply information, understand human societies and cultures, deepen their sense of values and ethics, and enrich their personal lives. Additionally, the general education core curriculum requirements equip students with the analytical, language, science, and mathematics skills necessary for the specific degree requirements of their majors. The courses and their sequence in the general education core curriculum requirements are designed specifically to achieve these objectives and to prepare students for success in subsequent courses.

New Mexico Higher Education General Education Core Competencies

New Mexico Tech teaches and assesses in compliance with the New Mexico Higher Education General Education Core Competencies established for Area 1: Communications; Area 2: Mathematics; Area 3: Basic Laboratory Sciences; Area 4: Social Sciences; and Area 5: Humanities.

Transfer Students

Transfer students are expected to meet these general requirements in principle but are not required to present the exact duplicates of these courses. Their transcripts will be evaluated by the Registrar.

Changes in the educational program are made from time to time by action of the Faculty Senate. Students in continuous residence are assured that care will be taken to avoid unnecessary hardship caused by such changes.

GPA Requirements

Some department require that their students achieve a minimum GPA in required courses. This information is listed by individual department. Student should consult their advisors for specific criteria.

General Education Core Curriculum Requirements for a Bachelor of Science Degree

Area 1– Communications (9 credit hours)

ENGL 111 (3) - ENGL 111 is waived for students who have a high enough ACT or SAT score (see the undergraduate catalog, page 36). These students must take another course to replace the three credit hours; however, that course does not have to be an English course.

ENGL 112 (3) - Must meet prerequisites to enroll, see page 38.

ENGL 341 (3) - Must meet prerequisites to enroll, see page 38. Mechanical Engineering majors must use MENG 341.

Area 2 - Mathematics (8 credit hours)

MATH 131 (4) - Must meet prerequisites to enroll, see page 93.

MATH 132 (4) - Must meet prerequisites to enroll, see page 93.

Area 3 - Basic Laboratory Sciences (18 credit hours)

PHYS 121 & 121L (5)

Physics majors may use PHYS 221 & 221L. Other students may substitute this sequence with permission of the Physics Department.

PHYS 122 & 122L (5)

Physics majors may use PHYS 222 & 222L. Other students may substitute this sequence with permission of the Physics Department.

CHEM 121 & 121L (4)

CHEM 121 & 121L; may be replaced by CHEM 151 & 151L

CHEM 122 & 122L (4)

CHEM 122 & 122L; may be replaced by CHEM 152 & 152L

Area 4 - Social Sciences (6 credit hours)

Economics (ECON)
Political Science (PS)
Psychology (PSY)
Anthropology (ANTH)
Women's and Gender Studies (WGS)

Area 5 - Humanities (6 credit hours)

English (ENGL), except ENGL 103, 111, 112, 341
Art History (ART)
Communication (COMM)
Music (MUS), except for performance ensembles
History (HIST)
Philosophy (PHIL)
Humanities (HUMA)
Technical Communication (TC) except TC 321, 420, 422
Theater (THEA)
Foreign Languages (SPAN, FREN, GERM)
Other languages may be counted only if they are listed or approved by the Communication, Liberal Arts, Social Sciences Department

Area 6 - Additional Courses from Area 4 or 5 (6 credit hours)

General Degree Requirements for a Master of Science Degree

The general requirements common to all M.S. degree curricula in the sciences and engineering fields are listed below. Additional requirements for specific curricula are listed under the appropriate department.

It is required that a student preparing for the M.S. degree:

1. Have competence in the subject matter of the standard introductory college courses in chemistry, physics, and one natural science,
2. Have a working knowledge of calculus and the content of one additional course in mathematics beyond calculus,
3. Have a minimum of six credit hours of approved upper-division or graduate course work from another department,
4. Declare a major with at least 12 credit hours of course work above the 500-level, exclusive of research credits, and
5. Complete a research project culminating in a thesis or independent study paper.

Note: These general requirements do not apply to students in the Master of Science for Teachers (MST) program. MST requirements are listed on page 122.

General Degree Requirements for a Doctor of Philosophy Degree

The degree of Doctor of Philosophy requires a high level of competence in a recognized field of learning, and only those students showing unusual promise are accepted. A dissertation that contributes to the general field of knowledge must be written and defended before a committee of the faculty.

In addition to dissertation credits, course requirements for each specialty are listed under the programs and courses of instruction for each department.

Arts & Sciences

Air Force ROTC (AFROTC)

Professor Robinson

Assistant Professors Bolin, Bradley

AFROTC Detachment 510
(Aerospace Studies Building 159)
MSC02 1650 / 1901 Las Lomas NE
1 University of New Mexico
Albuquerque, NM 87131-0001
(505)277-4502
Www.afrotc.com
Www.unm.edu/~erotcweb

The mission of the Air Force ROTC is to provide instruction and experience to all cadets in a diversified college or university environment, so they can graduate with the knowledge, character, and motivation essential to becoming leaders in the United States Air Force. The Air Force ROTC approach to education encourage inquiry, analysis, critical thinking, imagination, judgment, and individual participation on the part of each student.

The Air Force ROTC commissioning program is open to qualified students in all academic majors. The program is divided into a general military course (GMC) and a professional officer course (POC). The latter is the final commissioning phase for those students who qualify and desire a commission in the USAF. Both the GMC and POC programs require students to enroll in an Aerospace Science Leadership Laboratory each semester.

Program Requirements

Qualified students may enroll in aerospace studies classes during normal college registration procedures. The student enrolls in the General Military Course (GMC) for the first two years. Prior to enrolling the last two years of the program, the Professional Officer Course (POC), the student must meet Air Force ROTC qualification standards and requirements. In addition, all Air Force ROTC participants must complete a four-week summer field training course prior to entering the POC, normally between the sophomore and junior years. It is possible to compress the two GMC years to one through dual enrollment into the academic courses. The POC portion must last two years.

Financial Opportunities

The Air Force provides uniforms and textbooks for Air Force ROTC courses. Participants receive approximately \$600.00 for the four-week summer training period (in addition to travel pay and an airline ticket). After successful completion of the training and entrance into the POC, participants will receive up to \$500 a month (tax-free) subsistence for approximately 20 months (until graduation). Students who qualify may receive an AFROTC scholarship which will pay tuition and fees, up to \$900 per year for books and up to \$550.00 per month (tax-free) subsistence throughout the academic period that the scholarship is in effect. Scholarships are available for four, three and one-half, three, two and one-half, and two year periods. An additional year of scholarship benefits is available for most technical majors. Students who qualify for the POC and are not on AFROTC scholarships receive up to \$500.00 per month. To retain this scholarship, the student must continue to meet retention standards.

This department is administered by personnel of the United States Air Force under rules promulgated by the Department of the Air Force and New Mexico Tech.

Following successful completion of the Air Force ROTC program, each individual is commissioned as a second lieutenant in the United States. Full pay and benefits begin upon initial assignment to active duty.

Students may enter Air Force ROTC from any high school, college or university. Transfer students with a ROTC background can receive credit for previous ROTC experience.

Three Phases of the AFROTC Program

General Military Course (GMC)

The GMC is an introduction to the U.S. military forces and to the development of air and space power. The course of study is designed to prepare cadets for entry into the studies normally offered to freshmen and sophomores. The GMC total approximately 180 course hours, consisting of 60 course hours of academics and 120 course hours of leadership laboratory over two years. Four courses are required to complete the GMC: First year, AFAS 120 (fall semester), AFAS 121 (spring semester), second year; AFAS 250 (fall semester), AFAS 251 (spring semester). Sophomores may dual enroll in AFAS 120/121 and AFAS 250/251 to accomplish these requirements in two semesters instead of four.

Field Training

Field Training is a four week encampment at Maxwell AFB in Montgomery, AL, which is designed to evaluate the student while challenging them both mentally and physically. Upon successful completion of Field Training, the student is allowed to enter POC.

Professional Officer Course (POC)

POC subject matter includes theoretical and applied leadership, management, communication skills and national security and defense policy. The POC prepares cadets for active duty as commissioned officers in their junior and senior years. The POC totals approximately 300 hours, with 180 hours of academics and 120 hours of leadership laboratory over two years.

NOTE: Leadership laboratory is a co requisite each semester throughout the four-year program. Leadership laboratory provides a variety of practical leadership experiences by rotating cadet corps positions and responsibilities among students enrolled in the GMC and POC

General Military Courses

AFAS 120, The Foundation of the United States Air Force I, 1 cr

A survey course designed to introduce students to the United States Air Force and provide an overview of the basic characteristics, missions and organization of the Air Force.

AFAS 120L, Leadership Laboratory, 1 cr

Corequisite: AFAS 120

Development of personal leadership and managerial abilities. Examination and demonstration of Air Force customs and courtesies, drill and ceremonies and standards of discipline and conduct. Graded S/U.

AFAS 121 The Foundation of the United States Air Force II, 1 cr

A survey course designed to introduce students to the United States Air Force and provide an overview of the basic characteristics, missions and organization of the Air Force.

AFAS 121L, Leadership Laboratory

Corequisite: AFAS 121

Continuation of AFAS 120L. Graded S/U.

AFAS 250, The Evolution of USAF Air and Space Power I, 1 cr

Introduces topics on Air Force heritage and leaders, introduction to air and space power through examination of competencies, functions and continued application of communication skills.

AFAS 250L, Leadership Laboratory

Corequisite: AFAS 250

Application of elements of personal leadership. Demonstration of command, effective communications, individual leadership instruction, physical fitness training and knowledge of Air Force requirements. Graded S/U.

AFAS 251, The Evolution of USAF Air and Space Power II, 1-2 credits

Introduces topics on Air Force heritage and leaders, introduction to air and space power through examination of competencies, functions, and continued application of communication skills.

AFAS 251L, Leadership Laboratory, 1-2 cr

Corequisite: AFAS 251

Continuation of AFAS 250L. Graded S/U.

AFAS 300, Air Force Leadership Studies, 3 cr

Teaches cadets advanced skills and knowledge in management and leadership. Emphasis placed on enhancing leadership skills. Cadets have an opportunity to try out the leadership/management techniques in a supervised environment as juniors and seniors.

AFAS 300L, Air Force Leadership Laboratory

Corequisite: AFAS 300

Application of leadership and management theories and concerns through participation in advanced leadership experiences; weight and fitness training. Graded S/U.

AFAS 301, Air Force Leadership Studies, 3 cr

Teaches cadets advanced skills and knowledge in management and leadership. Emphasis placed on enhancing leadership skills. Cadets have an opportunity to try out the leadership/management techniques in a supervised environment as juniors and seniors.

AFAS 301L, Air Force Leadership Laboratory, 1 cr*Corequisite: AFAS 301*

Continuation of AFAS 300L. Graded S/U.

AFAS 400, Natl Security Affairs/Prep for Active Duty, 3cr

A foundation for seniors to understand their role as military officers in American society. An overview of the complex social and political issues facing the military profession.

AFAS 400L, Air Force Leadership Laboratory, 1cr*Corequisite: AFAS 400*

Application of leadership and management theories and concerns through participation in advanced leadership experiences; weight and fitness training.

AFAS 401, Natl Security Affairs/ Prep for Active Duty, 3cr

A foundation for seniors to understand their role as military officers in American society. An overview of the complex social and political issues facing the military profession.

AFAS 401L, Air Force Leadership Laboratory, 1 cr*Corequisite: AFAS 401*

Continuation of AFAS 400L. Graded S/U

These courses are taught through a special cross-enrollment agreement with the University of New Mexico and its Department of Aerospace Studies. Items required for the courses are provided by the AFROTC program.

Courses are taught on the main campus of UNM; students wishing to take these courses should contact the Aerospace Studies Department at 505.277.4502.

Atmospheric Sciences Interdepartmental Graduate Program

A number of departments at NM Tech offer coursework and research opportunities in the atmospheric sciences. This program was developed to:

- 1) make it easier for students to discern what is available at NM Tech in the atmospheric sciences and
- 2) facilitate cross-departmental course and research work by students.

The actual degrees awarded are those offered by each department; there is no separate degree in the atmospheric sciences. The student must satisfy all the requirements in his or her department to earn a degree. Each student shall have an academic advisor from the student's home department. However, the student's research advisor can be a faculty member from any of the participating departments.

Current Specialties

Atmospheric and environmental chemistry: Kyle, Wingenter

Cloud physics, cloud dynamics, and atmospheric electricity: Eack, Krehbiel, Raymond, Rison, Winn

Hydroclimatology: Hendrickx

Upper-atmosphere physics: Minschwaner, Thomas

Applicable Courses

Chemistry

CHEM 422, Environmental Geochemistry

CHEM 531, Chemistry of Aquatic Systems

CHEM 532, Atmospheric Chemistry

Earth and Environmental Science

ERTH 422, Environmental Geochemistry

GEOC 507, Hydrogeochemistry

HYD 503, Groundwater Hydrology

HYD 507, Hydrogeochemistry

HYD 512, Surface Water Hydrology

HYD 513, Hydroclimatology

HYD 517, Vadose Zone Hydrology

Environmental Engineering

ENVE 413, Fundamentals of Air Pollution Engineering

ENVE 416, Design of Air Pollution Engineering Systems

ENVE 535, Transport and Fate of Air Pollutants

Physics

PHYS 331, Physics of Weather and Climate I
 PHYS 332, Physics of Weather and Climate II
 PHYS 432, Atmospheric Remote Sensing
 PHYS 443, Atomic and Nuclear Physics
 PHYS 526, Fluid Dynamics
 PHYS 533, Advanced Topics in Atmospheric Physics

Participating Departments and Faculty

Chemistry

Wingenter—Atmospheric Chemistry

Earth and Environmental Science

Hendrickx—Vadose Zone Hydrology
 Kyle—Igneous Geochemistry, Antarctic Geology,
 Volcanology

Electrical Engineering

Rison—Atmospheric Electricity, Instrumentation
 Thomas—Upper Atmospheric Physics, Instrumentation

Environmental Engineering

Cal—Air Quality Engineering and Science

Materials and Metallurgical Engineering

G. Bond—Carbon Dioxide Remediation

Physics

Eack—Atmospheric Physics, Atmospheric Electricity
 Krehbiel—Lightning Studies, Radar Meteorology,
 Thunderstorm Electrification
 Minschwaner—Radiative Transfer and Climate, Physics of
 the Upper Atmosphere
 Raymond—Geophysical Fluid Dynamics, Cloud Physics,
 Clouds and Climate
 Winn—Atmospheric Physics, Electrical Discharges in
 Gases, Instrumentation

Basic Sciences Program (Interdepartmental)

Administrative Committee for Basic Sciences:

Jeff Altig, Chemistry

Mark Samuels, Psychology

David Westpfahl, Physics

Ex Officio: Dean of Arts & Sciences (Chair)

Degrees Offered: B.S. in Basic Sciences

The degree Bachelor of Science in Basic Sciences is intended for the student who desires a Bachelor of Science degree but wishes more latitude in the selection of courses than is available otherwise. It is well adapted to the needs of a student who may wish to complete preparation for secondary school teaching in science or mathematics. For this purpose, however, proper selection of courses is necessary, and the advice of the Department of Education should be sought.

To qualify for the degree Bachelor of Science in Basic Sciences, a student must satisfy the general education core curriculum requirements for the Bachelor of Science degree (page 7).

- Of the minimum 130 credit hours required for this degree, at least 65 must be in science and mathematics. These can include biology, chemistry, computer science, earth and environmental science, mathematics, engineering courses (numbered above 200), physics, and psychology.
- At least 30 of these credit hours must be in courses numbered 201 or above. In order that a reasonable depth of study is attained in at least two fields, the 30 credit hours must include at least nine credit hours in each of two fields.
- The foreign language requirement is six credit hours in a single language.
- Of the total credit hours required, at least 42 must be in courses numbered 300 or above.

Biology

Professors Kieft, Rogelj (Chair of the Department)

Associate Professors Kirk, Reiss

Adjunct Faculty: Bhasker, Boston, Elliott, Markwell, Pias,

Piyasena, Tartis, Thompson, Vuyisich, D. Wilkinson, P.

Wilkinson

Emeritus Faculty: Shortess, Smoake

Degrees Offered: B.S. in Biology, Biology with Environmental Science Option, and Biology with Medical Technology Option; M.S. in Biology and M.S. in Microbiology

Program Offered: 5 year BS/MS Program

The mission of the Biology Department is to provide students with a relevant education for biomedical and biotechnological careers, to lead in molecular biological research, and to serve the university and the scientific community. The Biology program prepares undergraduate students for graduate education in the medically allied professions and in the specialized fields of the biological sciences. (Students who are interested in pre-medical, pre-dental, and pre-veterinary science programs should see page 117) A wide variety of career opportunities is currently available for those individuals possessing advanced knowledge and skills, particularly in the areas of biochemistry, molecular biology, microbiology, ecology, genetics, endocrinology, and immunology. Market demand in these areas will likely remain strong for the foreseeable future.

Undergraduate majors typically have diverse career goals and objectives. To accommodate these differences, the undergraduate program is very flexible; only a minimal number of technical core courses is required. Through the selection of appropriate technical electives, each student customizes their education based on personal academic needs and career objectives.

The main approach in the classroom is to stress the highly quantitative and analytical nature of modern biological inquiry, which utilizes sophisticated biochemical and biophysical techniques to answer fundamental questions about living organisms. Undergraduates are encouraged to undertake research through various directed study and special topics offerings and are often employed as technicians in the research laboratories of the faculty.

Program Educational Objectives:

Our graduates will be able to use basic principles of science to analyze, to explain, and to apply biological information and concepts.

Our graduates will be able to design and implement biological research and report findings orally and in writing.

Undergraduate Program

Bachelor of Science in Biology

Minimum credit hours required—130

In addition to the General Education Core Curriculum Requirements (page 7), the following courses are required:

- BIOL 111 (3), 111L (1), 112 (3), 112L (1), 311 (3), 311L (1), 331 (3), 333 (3) & 333L (1) or 341 (3) & 341L, and BIOL 471 (1)
- At least 6 additional credit hours from: BIOL 341 (3) & 341L (1) or 333(3) & 333L (1), 351 (3), 351L (1), 352 (3), 352L (1), 431 (3), 437 (3)
- At least 6 additional credit hours from: BIOL 343 (3), 343L (1), 344 (3), 344L (1), 444 (3), 446 (3), 455 (3)
- Additional Biology (12). CHEM 441 and 442 (Biochemistry I and II) may be applied to biology electives.
- CHEM 333 (3); plus 6 additional hours of the following: CHEM 311 (3–4), 331 (3–4), 333L (1), 334 (3), 334L (1), 441 (3–4)
- Computer Science or Mathematics: CSE 113 (4) or MATH 283 (3)
- Electives to complete 130 hours

Biology laboratory classes are required for biology lecture courses that offer an associated laboratory if credit for the lecture course is used to meet the required number of biology credits for a degree in biology. Students pursuing a B.S. in Biology must take Biology and Chemistry courses for a letter grade, except for BIOL 101 and BIOL 102. Prerequisites for a particular course may be waived only with the written permission of the course instructor and chair of the department.

Sample Curriculum for the Bachelor of Science in Biology

Semester 1

- 4 BIOL 111 & 111L (intro)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 4 MATH 131 (calculus)
- 1 Physical Recreation

16 Total Credit Hours

Semester 2

- 4 BIOL 112 & 112L (intro)
- 4 CHEM 122 & 122L (general)
- 3 ENGL 112 (college English)
- 4 MATH 132 (calculus)
- 1 Physical Recreation

16 Total Credit hours

Semester 3

- 4 BIOL 311 & 311L (genetics)
 - 3 BIOL 331 (cell)
 - 3 Social Science
 - 5 PHYS 121 & 121L (general)
 - 3 CHEM 333 (organic)
- 18 Total credit hours

Semester 4

- 4 BIOL 333 & 333L (molecular)
 - 3 Social Science
 - 3 Humanities
 - 5 PHYS 122 & 122L (general)
 - 3 Chemistry Elective
- 18 Total credit hours

Semester 5

- 4 Biology Elective
 - 3 Biology Elective
 - 3 Chemistry Elective
 - 3 Social Science
 - 3 ENGL 341 (technical writing)
- 16 Total credit hours

Semester 6

- 4 Biology Elective
 - 3 Biology Elective
 - 3-4 CSE 113 (computer science) or
MATH 283 (statistics)
 - 3 Humanities
 - 3 Electives
- 16-17 Total credit hours

Semester 7

- 4 Biology Elective
 - 3 Biology Elective
 - 1 BIOL 471 (seminar)
 - 8 Electives
- 16 Total credit hours

Semester 8

- 4 Biology Elective
 - 3 Biology Elective
 - 3 Humanities/Social Science
 - 6 Electives
- 16 Total credit hours

Bachelor of Science in Biology with Environmental Science Option

Minimum credit hours required—130

In addition to the General Degree Requirements (page 7), the following courses are required:

- BIOL 111 & 111L (4), 112 & 112L (4), 311 & 311L (4), 331 (3), 333 & 333L (4), or BIOL 343 & 343L, and BIOL 471 (1)
- At least 12 additional credit hours from: BIOL 343 (3), 343L (1), 344 (3), 344L (1), 444 (3), 446 (3), 455(3), 493 (4); CHEM 422 (3), 422L (1), EARTH 340 (3), 390 (3), 422 (3), 440 (3)
- Additional Biology (12) CHEM 441 and 442 (Biochemistry I and II) may be applied to biology electives.
- CHEM 333 (3); plus 6 additional hours of the following: CHEM 311 (3-4), 331 (3-4), 333L (1), 334 (3), 334L (1), 422 (3-4), 441 (3-4)
- Computer Science or Mathematics: CSE 113 (4) or MATH 283 (3)
- Electives to complete 130 hours

Biology laboratory classes are required for biology lecture courses that offer an associated laboratory if credit for the lecture course is used to meet the required number of biology credits for a degree in biology. Students pursuing a B.S. in Biology must take Biology and Chemistry courses for a letter grade, except for BIOL 101 and BIOL 102. Prerequisites for a particular course may be waived only with the written permission of the course instructor and chair of the department.

Bachelor of Science in Biology with Medical Technology Option

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- BIOL 111 & 111L (4), 112 & 112L (4), 341 & 341L (4), 437 (3), BIOL 351 (3), BIOL 352 (3)
- CHEM 311 & 311L (4), 333 & 333L (4)
- MATH 283 (3)
- Internship (63) at an approved school of medical technology

Minor in Biology

Minimum credit hours required—18

The following courses are required:

- BIOL 111 & 111L (4)
- BIOL 112 & 112L (4)
- BIOL 331 (3)
- BIOL 344 & 344L (4)
- Additional biology course numbered 300 or above (3)

Biology classes required for a minor in biology may not be taken on an S/U basis.

Minor in Geobiology

Minimum credit hours required — 18

The following courses are required:

- EARTH 101 (3), EARTH 101L or 103L (1), EARTH 201 & 201L (4)
- BIOL 111 & 111L (4)
- Two classes from the following list: EARTH 450 (3), EARTH 390 (3), BIOL 341 (3), BIOL 344 (3), EARTH 449/BIOL 449 (3)

Graduate Program

Master of Science in Biology

The master's candidate must demonstrate competence in mathematics, chemistry, and physics comparable to New Mexico Tech's Bachelor of Science in Biology. Requirements for the Master of Science degree in Biology follow the M.S. with Thesis option (see Graduate Catalog). Additional requirements are the following:

- Completion of at least six credit hours of 500-level biology coursework other than thesis, directed study, or seminar.
- Completion of at least six credit hours of 500-level coursework other than thesis, directed study, or seminar in one or more disciplines outside of biology.
- Completion of two credit hours of BIOL 501, Graduate Seminar.

Five Year Program: Biology B.S./Biology M.S.

Exceptionally well motivated students may earn both BS and MS degrees in Biology in five years. The student fulfills the requirements for a BS degree in four years and for an MS degree the following year. A minimum of 160 credit hours are required to complete both degrees. The MS degree requires the completion of a thesis based on the student's own research.

Students may apply for the BS/MS program at the end of their 4th semester. Admission is contingent on their having a GPA of at least 3.0, and on the acceptability of their proposed course of study. Students with upper division standing may also apply, with the same requirements for admission.

Students in the five-year program must apply for graduate standing, normally in their 6th semester. Once admitted to the graduate program, the student spends his or her 8th semester as a dually registered student. During their senior year, the student must select a graduate advisory committee and formalize his or her graduate research topic. Once admitted to the graduate program, a student may apply for financial support via research assistant or teaching assistant positions.

Biology Courses:

BIOL 101, Issues in Biological Science, 1 cr, 1 cl hr

Graded S/U

Introduction to modern topics in biotechnology, biodiversity, and biocomplexity. Discussion of career options in the biological sciences.

BIOL 111, 111L, General Biology, 4 cr, 3 cl hrs, 2 lab hrs

Corequisite: CHEM 109 or CHEM 121

A survey of life functions and associated structures at the cellular level. Energy fixation and utilization, growth and development through cell division, and gene action. [NMCCNS BIOL 1214: General Education Area III]

BIOL 112, 112L, General Biology II, 3-4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: BIOL 111

Introduction to evolution, ecology, physiology, and development. Laboratory is a phylogenetic survey of the kingdoms of life. [NMCCNS BIOL 1224: General Education Area III]

BIOL 311, 311L, Genetics, 3-4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: BIOL 111 & 111L; concurrent enrollment in 311R highly recommended.

An overview of the storage, transmission and expression of biological information. The lab emphasizes Mendelian analysis in model organisms and fluorescent analysis of human DNA.

BIOL 311R, Genetics Recitation, 1 cr, 1cl hrs

Corequisite: Biol 311

BIOL 331, Cell Biology, 3 cr, 3 cl hrs

Prerequisites: BIOL 111; CHEM 121

Studies of life at the cellular level. The structure and functions of eukaryotic cells and their organelles. The molecular basis for energy transfers, growth and development, and their regulation.

BIOL 333, 333L, Molecular Biology, 3-4 cr, 3 cl hr, 3 lab hrs

Prerequisites: BIOL 331; CHEM 121

Principles of modern molecular biology. Laboratory emphasizes enzyme purification and recombinant DNA techniques, organized as a gene cloning project. BIOL 333 and BIOL 333L must be taken concurrently.

BIOL 341, 341L, Introductory Microbiology, 3-4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: CHEM 122

Corequisite: BIOL 331

A comparative study of reproduction, growth, and metabolism of bacteria, rickettsia, and viruses, with emphasis on the bacteria and their relation to man and their environment.

BIOL 343, 343L, Environmental Microbiology, 3–4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: BIOL 111

Corequisite for Biology majors: BIOL 331; BIOL 331 recommended for other majors

A study of the relationship between microorganisms and water and soil environments with emphasis on biogeochemical cycles.

BIOL 344, 344L, Introductory Ecology, 3–4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: BIOL 112; MATH 131

A study of the principles which govern the interactions between biological populations and the environment.

BIOL 351, Anatomy and Physiology I, 3 cr, 3 cl hrs

Prerequisite: BIOL 112; 331

Principles of human anatomy and physiology. Provides a general overview of the form and function of the following human systems: integumentary skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, immune, respiratory, digestive, urinary, and reproductive.

BIOL 351L, Anatomy and Physiology Lab I, 1 cr, 3 lab hrs

Corequisite: BIOL 351

An in-depth study of human anatomy and physiology, covering microanatomy and gross anatomy of multiple systems as well as physiological function. Focal systems will include: skeletal, muscular, gastrointestinal, cardiovascular, respiratory systems and the special senses.

BIOL 352, Anatomy and Physiology II, 3 cr, 3 cl hrs

Prerequisite: BIOL 351

A continuation of BIOL 351 with more in-depth study of human physiology. Topics will include a variety of physiology systems and expand on systems covered in BIOL 351 and human development.

BIOL 352L, Anatomy and Physiology Lab II, 1 cr, 3 lab hrs

Prerequisite: BIOL 351

Corequisite: BIOL 352

An in-depth study of human anatomy and physiology, covering microanatomy and gross anatomy of multiple systems as well as physiological function. Focal systems will include: skeletal, muscular, gastrointestinal, cardiovascular, respiratory systems and the special senses.

BIOL 362, Animal Behavior, 3 cr, 3 cl hrs

Prerequisites: PSY 121; BIOL 112; or consent of instructor

General overview of ethological and physiological approaches to the study of animal behavior. (Same as PSY 362)

BIOL 411, Advanced Genetics, 3 cr, 3 cl hrs

Prerequisites: BIOL 311 and 333

A study of current topics in genetics, including the molecular basis of gene structure and action in eukaryotes and prokaryotes.

BIOL 431, Virology, 3–4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: BIOL 331

Corequisite: BIOL 311

Molecular biology of viral infection, replication, and pathogenesis. Animal viruses emphasized.

BIOL 435, 435D, Bioinformatics, 3 cr, 3 cl hrs

Prerequisite: BIOL 311 or consent of instructor

Computer analysis of biological sequence data used to perform in silico experiments. Students will design and perform experiments using public domain software and databases.

BIOL 437, Infection and Immunity, 3 cr, 3 cl hrs

Prerequisite: BIOL 341

Study of human infectious disease and the immune system. Pathogenic microorganisms and mechanisms of pathogenicity. Innate and acquired immune responses. Disease ecology and evolution in infectious disease systems.

BIOL 444, Evolutionary Biology, 3 cr, 3 cl hrs,

Prerequisite: BIOL 311, BIOL 344

The mechanisms and implications of biological evolution. Topics include population genetics, adaptation and natural selection, fossil evidence, and evolutionary medicine.

BIOL 446, Environmental Toxicology, 3 cr, 3 cl hrs

Prerequisite: CHEM 333

The fate and behavior of toxic pollutants in terrestrial and aquatic environments, from an ecosystem perspective.

BIOL 449 Astrobiology, 3 cr, 3 cl hours

Prerequisites: CHEM 121, 122, PHYSICS 121, 122, plus one other science course and consent of instructor. Offered on demand.

An in-depth and interdisciplinary study of astrobiology, including interactions between living and non-living systems at multiple scales: stellar, planetary, meso, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principles of astrophysics, geosciences, planetary science, chemistry, and biology. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with BIOL 549, with additional expectations for graduate credit. (Same as EARTH 449.)

BIOL 455, Molecular Ecology, 3 cr, 3 cl hrs

Prerequisites: BIOL 311 and 344, or consent of instructor

Application of molecular biological techniques to ecological and environmental problems. Current research projects at Tech are emphasized.

BIOL 471, Life Sciences Seminar, 1 cr, 1 cl hr

Prerequisite: Upper-class standing in biology or consent of instructor

Review, discussion, and student presentations of the current literature on a single topic in biology. Topics are chosen with the aim of integrating multiple levels of biological organization and research approaches.

BIOL 481, FreeStyle BioSciences, 1 cr, 2 cl hr

Prerequisite: Senior or Graduate Standing

Exploratory, interdisciplinary seminar-style class utilizing web resources focused on recent developments in Biology and Biology-related areas.

BIOL 486, Cytogenetics, 3 cr, 3 cl hrs

Prerequisites: BIOL 311 and 333

Principles of chromosome structure and function with an emphasis on medical diagnostics. Course includes a field trip to a cytogenetics diagnostic laboratory.

BIOL 487, 487L. Advanced Virology, 3-4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: BIOL 431 or 531

An in-depth study of one or two viruses, viral vectors for gene therapy, and herpes or hemorrhagic fever viruses. The laboratory section of the course will include viral propagation in tissue culture and methods to investigate the molecular biology of viral infection.

BIOL 488, Biology of Cancer, 3 cr, 3 cl hrs

Prerequisites: BIOL 331 and 333

Principles and molecular mechanisms of carcinogenesis. Involves elements of cell biology, genetics, molecular biology, immunology, biochemistry, virology, pharmacology, physiology, developmental biology, and pathology.

BIOL 489, 489D, Special Topics in Biology, cr and hrs to be arranged

Prerequisites: Two semesters of advanced courses and consent of instructor

Special readings or course in biology.

BIOL 491, Special Problems, cr and hrs to be arranged

Prerequisites: Two semesters of advanced courses and consent of instructor

An introduction to methods of research. Problems are chosen from the fields of biology and may be small independent investigations or part of a research program being directed by the advisor.

BIOL 493, Directed Study in Environmental Biology, cr and hrs to be arranged

Prerequisites: Senior student majoring in Biology—Environmental Science Option, and consent of instructor

A student-designed study of local problems and processes occurring during interaction between biological systems and their physico-chemical environment including literature review, field and laboratory research, and result presentation by written report and seminar.

BIOL 495, Biomedical Senior Thesis I, 3 cr

For Biomedical Science majors. Mentored, problem-oriented biomedical research under the direction of a faculty member. Students should consult with their academic advisor and with various Biology faculty to identify a Thesis advisor. Near the end of the semester, students will give a formal research presentation.

BIOL 496, Biomedical Senior Thesis II, 3 cr

For Biomedical Science majors. Continuation of BIOL 495. Students are required to write a paper on the research project and to give an oral presentation.

BIOL 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements. Research under the guidance of a faculty member.

BIOL 501, Graduate Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate-level standing or consent of instructor

Special topics in biology. Readings, student presentations, and discussions will focus on a single topic within biology, with a different topic to be selected by the Biology faculty each semester.

BIOL 511, Advanced Genetics, 3 cr, 3 cl hrs

Prerequisites: BIOL 311 and 333

A study of current topics in genetics, including the molecular basis of gene structure and action in eukaryotes and prokaryotes. Shares lecture with BIOL 411, but is graded separately and additional graduate-level work is required.

BIOL 531, Virology, 3 cr, 3 cl hrs

Prerequisite: BIOL 331

Corequisite: BIOL 311

Molecular biology of viral infection, replication, and pathogenesis. Animal viruses emphasized. Shares lecture with BIOL 431, but is graded separately and additional graduate-level work is required.

BIOL 535, 535D, Bioinformatics 3 cr, 3 cl hrs

Prerequisite: BIOL 311 or consent of instructor

Computer analysis of biological sequence data used to perform in silico experiments. Students will design and perform experiments using public domain software and databases. Shares lecture with BIOL 435, but is graded separately and additional graduate-level work is required.

BIOL 537, Infection and Immunity, 3 cr, 3 cl hrs

Prerequisite: BIOL 341

Study of human infectious disease and the immune system. Pathogenic microorganisms and mechanisms of pathogenicity. Innate and acquired immune responses. Immunochemistry, cellular immunity, and immunopathology. Shares lecture with BIOL 437, but is graded separately and additional graduate-level work is required.

BIOL 542, Advanced Microbiology, 3 cr, 3 cl hrs

Prerequisite: BIOL 341 or consent of instructor

A study of the current topics in structure, function, genetics, and biochemistry of microorganisms, with emphasis on recent scientific literature. Medical and environmental topics will be covered.

BIOL 544, Evolutionary Biology, 3 cr, 3 cl hrs

Prerequisite: BIOL 311, BIOL 344; graduate standing or consent of instructor.

The mechanisms and implications of biological evolution. Topics include population genetics, adaptation and natural selection, fossil evidence, and evolutionary medicine. Shares lecture with BIOL 444, but is graded separately and additional graduate-level work is required.

BIOL 549 Astrobiology, 3 cr, 3 cl hours

Prerequisites: Graduate status or consent of instructor. Offered on demand.

An in-depth and interdisciplinary study of astrobiology, including interactions between living and non-living systems at multiple scales: stellar, planetary, meso, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principles of astrophysics, geosciences, planetary science, chemistry, and biology. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with BIOL 449, with additional expectations for graduate credit. (Same as GEOL 549.)

BIOL 560, Population and Community Ecology, 3 cr, 3 cl hrs

Prerequisites: BIOL 344; graduate standing or consent of instructor

Advanced study of demography, population dynamics, species interactions, and community structure.

BIOL 564, Molecular Ecology, 3 cr, 3 cl hrs

Prerequisite: BIOL 333 or consent of instructor

Molecular ecology is the application of molecular genetics to ecological and environmental issues. The current literature in the field is reviewed. Participants choose a topic to research and develop a research proposal as the final project. Graduate students present a public seminar.

BIOL 581, Directed Study, cr to be arranged

Study under the guidance of a member of the biology staff. In general, subject matter will supplement that available in other graduate offerings in biology.

BIOL 586 Cytogenetics, 3 cr, 3 cl hrs

Prerequisites: BIOL 311 and 333

Principles of chromosome structure and function with an emphasis on medical diagnostics. Course includes a field trip to a cytogenetics diagnostic laboratory. Shares lecture with BIOL 486, but is graded separately and additional graduate-level work is required.

BIOL 587, 587L Advanced Virology, 3–4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: BIOL 431 or 531

An in-depth study of one or two viruses, viral vectors for gene therapy; and herpes or hemorrhagic fever viruses. The laboratory section of the course will include viral propagation in tissue culture and methods to investigate the molecular biology of viral infection. Shares lecture and lab with BIOL 487, 487 L, but is graded separately and additional graduate-level work is required.

BIOL 588, Biology of Cancer, 3 cr, 3 cl hrs

Prerequisites: BIOL 331 and 333

Principles and molecular mechanisms of carcinogenesis. Involves elements of cell biology, genetics, molecular biology, immunology, biochemistry, virology, pharmacology, physiology, developmental biology, and pathology. Graduate students are required to write a grant proposal.

BIOL 591, Thesis (master's program), cr to be arranged

Faculty Research Interests

Bhasker—Medical Professions

Boston - Geomicrobiology

Elliott— Neuroscience, Animal Communications, and
Psycholinguistics

Kieft— Microbiology, Environmental Biology

Kirk—Biology of Aging, Evolutionary Ecology

Markwell—Medical Professions

Pias— Biochemistry & Computer Simulations of
Biological Phenomena

Piyasena— Analytical Tools for Environmental,
Biological, and Chemical Analysis

Reiss—Molecular Genetics, Evolution

Rogelj— Cell Biology, Pathogen Detection, Drug
Discovery

Tartis—Chemical Engineering of Drug Delivery Systems

Thompson—Cell and Molecular Neuroscience of Vision

Vuyisich—Genome Science & Technology Applications

Dean Wilkinson—Veterinary Professions

Pepita Wilkinson—Veterinary Professions

Smoake— Animal Physiology, Endocrinology

Biomedical Sciences

Biomedical Sciences Advisory Committee:

Snezna Rogelj, Biology

Sally Pias, Chemistry

Mark Samuels, Psychology

Michaelann Tartis, Chemical Engineering

Bhaskar Majumdar, Materials Engineering

David Grow, Mechanical Engineering

Ex Officio: Dean of Arts & Sciences, Dean of Engineering

Degrees Offered: B.S. in Biomedical Sciences, with options in Biology, Chemistry and Cognitive Neuroscience

The Bachelor of Science in Biomedical Sciences is a broadly interdisciplinary degree, drawing on knowledge from both science and engineering. Students take a common set of core courses from several disciplines. For more in-depth study, they select an option in Biology, Chemistry, or Psychology along with a concentration in one of four engineering fields: Biochemical Engineering, Bioinformatics, Biomaterials, or Biomechanics.

Undergraduate Program

Core requirements for the Bachelor of Science in Biomedical Sciences (all options)

Minimum credit hours required – 130

In addition to the General Education Core Curriculum Requirements (page 7), the following core program is required of all Biomedical Sciences students. Note that courses marked with an asterisk () may also be used to satisfy General Education requirements:*

- BMS 101 (1), BMS 300 & 300L (4)
- BIOL 111 & 111L (4), BIOL 331 (3), BIOL 341 (3), BIOL 351 & 351L (4), BIOL 437 (3)
- CHEM 333 & 333L(4), CHEM 334 & 334L (4), CHEM 441 & 441L (4)
- CSE 107 & 107L (4) or CSE 113 & 113L (4) or ES 111 & 111L (3)
- MATH 231 (4), MATH 335 (3), MATH 383 (3)
- PHIL 342 (3)*
- PSY 121 (3)*, PSY 309 & 309L (4)*
- BIOL 495 (3) or CHEM 495 (3) or PSY 495 (3)
- BIOL 496 (3) or CHEM 496 (3) or PSY 496 (3)
- One of the science options described below
- One of the engineering concentrations described below

Bachelor of Science in Biomedical Sciences with Biology Option

In addition to the General Education Core Curriculum Requirements (page 7), and the core Biomedical Sciences Requirements (above), the following courses are required:

- BIOL 333 & 333L (4), BIOL 352 & 352L (4), BIOL 435 (3)

Bachelor of Science in Biomedical Sciences with Chemistry Option

In addition to the General Education Core Curriculum Requirements (page 7), and the core Biomedical Sciences Requirements (above), the following courses are required:

- CHEM 311 & 311L (4), CHEM 331 & 331L (4), CHEM 442 & 442L (4)

Bachelor of Science in Biomedical Sciences with Cognitive Neuroscience Option

In addition to the General Education Core Curriculum Requirements (page 7), and the core Biomedical Sciences Requirements (above), the following courses are required:

- PSY 205 (3)*, PSY 212 (3)*, PSY 312 (3)*, PSY 409 (3)*

Engineering Concentrations

Biochemical Engineering

- ChE 326 (3) and two of ChE 4xx (3), ChE 4yy (3)

Bioinformatics

- BIOL 311 & 311L (4), BIOL 333 & 333L (4), (part of Biology Option), BIOL 435 (3)
- CSE 122 (3), CSE 373 (3)

Biomaterials

- MATE 202 & 202L (4), MATE 310 (3), MATE 420 (3)

Biomechanics

- ES 201 (3), ES 216 (3), ES 303 (3)
- MENG 460 (3)

Biomedical Sciences Courses:

BMS 101, Introductory Biomedical Sciences, 1 cr, 1 cl hr

A discussion-focused course exploring current topics in biomedical research and innovation. The course promotes a broad view of the biomedical sciences and related challenges, with class discussions stimulated largely by TED talks and other internet videos.

BMS 300, 300L, Biotechnology and Lab, 3-4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: BMS 101, BIOL 111, CHEM 121

An overview of research in biomedicine, bioinformatics, bioprocesses, and biorobotics. Attention also given to moral and ethical issues. Lab projects are integral to the course.

Chemistry

Professors: Heagy (Associate Chair)

Associate Professors: Altig (Chair), Frolova, Wingenter

Assistant Professors: Pias, Piysena, Ranasinghe,

Rubasinghe, Tello Aburto

Adjunct Faculty: Clewitt, Elliott, Kalugin, Kirk, Kornienko

Research Faculty: Frolova

Instructors: Chang, Kombarakaran

Emeritus Professors: Brandvold, Brower, Hatch, Popp

Degrees Offered: B.S. in Chemistry, B.S. in Chemistry with Environmental Science Option, and B.S. in Chemistry with Biochemistry Option; M.S. in Chemistry and M.S. in Chemistry with Biochemistry Option; Ph.D. in Chemistry

The fundamental mission of the Department of Chemistry is to provide students with: (1) the skills necessary for critical and analytical thinking; (2) an understanding of the basic concepts of chemistry; (3) an appreciation of chemistry and its central place among the sciences; (4) a feeling for the joys and frustrations of original research; and (5) the ability to communicate observations and discoveries.

The Department of Chemistry offers a balance between pure and applied chemistry and presents science as part of a liberal education. The faculty is qualified in the major divisions of chemistry—inorganic, organic, analytical, physical, and biochemical. The undergraduate program emphasizes development of a strong foundation in the fundamental areas of chemistry in order to prepare students for the diverse career opportunities available to chemists. Laboratory facilities support research in all major areas of chemistry, with a focus on environmental and biomedical topics. Interdisciplinary work is encouraged. The department maintains a full complement of modern analytical instrumentation. Most undergraduate students participate in departmental research. Career possibilities range from industrial process control through scientific research in academic and government laboratories. More than 60 percent of Tech chemistry graduates continue their education in graduate school. Many have become teachers, medical doctors, or research scientists. The student has freedom to select courses to meet individual interests and objectives, such as preparation for graduate school or industry, or simply a superior education. Graduates receive a Bachelor of Science degree accredited by the American Chemical Society, and the chemistry curriculum is approved by the Committee on Professional Training of the American Chemical Society.

Undergraduate Program

Bachelor of Science in Chemistry

Minimum credit hours required—130

In addition to the General Education Core Curriculum

Requirements (page 7), the following courses are required:

- MATH 231 (4)
- CHEM 311 (3), 311L (1), 331 (3), 331L (1), 332 (3), 332L (1), 333 (3), 333L (1), 334 (3), 334L (1), 411 (3), 411L (1), 441 (3), 443 (3), 443L (1), 493 (1), 494 (2);
- Advanced Chemistry courses: Any three 400 or 500 level Chemistry courses not required above
- Advanced Chemistry labs: Any two 400 or 500 level Chemistry laboratory courses not required above

This leaves a minimum of 20 credit hours of electives. The Chemistry Department promotes a diverse set of electives for a well-founded education.

Recommended electives include BIOL 333, CSE 113, MATH 254, MATH 283, MATH 335, ES 110, ES 111, ChE 326, ENVE 201, MATE 202, and EARTH 20X. The probable sequence of electives should be discussed with the student's advisor during the freshman year. Students interested in admission to medical school (or other professional schools) should see *Preprofessional Programs* on page 117 for advice on choosing electives.

Sample Curriculum for the Bachelor of Science in Chemistry

This curriculum assumes a reasonably strong high school background. Where possible, CHEM 311, 333, and 334 should be completed by the end of the sophomore year. This is only a sample curriculum. Students should consult their advisor to design programs that fit their individual backgrounds, math placement, and interests.

Semester 1

4 CHEM 121 & 121L (general)

3 ENGL 111 (college English)

4 MATH 131 (calculus)

4 Electives

15 Total credit hours

Semester 2

4 CHEM 122 & 122L (general)

3 ENGL 112 (college English)

4 MATH 132 (calculus)

5 PHYS 121 & 121L (general)

16 Total credit hours

Semester 3

4 CHEM 311 & 311L (quantitative analysis)

4 CHEM 333 & 333L (organic)

4 MATH 231 (calculus)

5 PHYS 122 & 122L

17 Total credit hours

Semester 4

4	CHEM 334 & 334L (organic)
4	CSE 113 or ES 111 (programming)
3	Humanities
3	Social Science
<u>3</u>	Electives
17	Total credit hours

Semester 5

4	CHEM 331 & 331L (physical)
3	Humanities
3	Social Science
<u>5</u>	Electives
15	Total credit hours

Semester 6

4	CHEM 332 & 332L (physical)
3	ENGL 341 (technical writing)
3	Social Science
<u>6</u>	Electives
16	Total credit hours

Semester 7

4	CHEM 411 & 411L (instrumental)
3	CHEM 441 (biochemistry)
4	Advanced Chemistry
1	CHEM 493 (senior thesis)
3	Humanities/Social Science
<u>3</u>	Electives or Advanced Chemistry
18	Total credit hours

Semester 8

4	CHEM 443 & 443L (inorganic)
4	Advanced Chemistry
2	CHEM 494 (senior thesis)
<u>6</u>	Electives or Advanced Chemistry
16	Total credit hours

Bachelor of Science in Chemistry with Environmental Science Option*Minimum credit hours required—130**In addition to the General Education Core Curriculum Requirements (page 7), requirements include the courses listed for the Bachelor of Science in Chemistry and the following courses:*

- CHEM 422 and CHEM 422L plus 8 credit hours from the following: CHEM 431, 432, or 433; BIOL 343, 344, 446, and 455; EARTH 130, 130L, 140, 140L, 200, 201, 202, 340, 390, and 405

Bachelor of Science in Chemistry with Biochemistry Option*Minimum credit hours required—130**In addition to the General Education Core Curriculum Requirements (page 7), requirements include the courses listed for the Bachelor of Science in Chemistry and the following courses:*

- CHEM 441L (1), 442 (3), 442L (1)
- Six credit hours from the following: CHEM 447; BIOL 311, 331, 333, 341, 343, 351, 352, 411, 431, 435, 437, 471, 486, 487, and 488; ChE 476; and any associated laboratory courses

Minor in Chemistry*Minimum credit hours required—19**The following courses are required:*

- Chemistry 311 (3) & 311L (1)
- Three of the following courses with the associated labs: Chemistry 331 (3) & 331L (1), Chemistry 332 (3) & 332L (1), Chemistry 333 (3) & 333L (1), Chemistry 334 (3) & 334L (1)
- One chemistry course numbered 400 or above (3-4)

Graduate Program

Students entering any chemistry graduate program must take entrance examinations within a week after their first registration. If deficiencies are determined, appropriate remedial undergraduate coursework will be required. Remedial coursework does not count toward degree requirements. The student's course of study must be approved by the student's advisory committee and must fulfill the general degree requirements for their respective advanced degree.

Master of Science in Chemistry

M.S. students must meet the general degree requirements for the Master of Science degree at New Mexico Tech. In addition, a minimum of 12 credit hours of 500-level chemistry courses are required. CHEM 529 and 530 do not count towards this requirement. Additionally students must take 6 credit hours at the 300, 400, or 500-level and above from other departments. The student should consult with their committee and advisor when developing a course plan.

Master of Science in Chemistry with Biochemistry Option

Students earning a Master of Science degree in chemistry can receive a Biochemistry. The requirements for the biochemistry option are the same as those for a Master of Science in Chemistry, except that:

- Six (6) credit hours of the 12 credit hours minimum of 500-level chemistry classes must be from CHEM 521 and 547.
- A maximum of three (3) credit hours of CHEM 581 or BIOL 581 (directed study) may be used toward the degree.
- A minimum of six (6) credit hours of courses in biology, selected from the following, must be completed: BIOL 331, 333, 351, 352, 356, 488, 501, 552, 588.

Doctor of Philosophy in Chemistry

Students of exceptional ability may pursue a program leading to the doctoral degree. The prospective doctoral candidate will develop a broad background in chemistry and related fields and prove his or her ability to do independent research. An early assessment of the student's ability is achieved in the candidacy examination to be completed by the end of the second year. Research in Chemistry is focused on environmental and human health related topics.

Interdisciplinary programs with other science departments, such as Physics, Biology, or Earth and Environmental Science can be pursued. Ph.D. students must meet the general degree requirements for the Doctor of Philosophy degree at New Mexico Tech as well as the requirements listed below.

No Prior Master's Degree

A minimum of 50 credit hours is required. These hours are distributed as follows:

500-level chemistry courses	21 cr hrs minimum
CHEM 529, 530 (Seminar)	2 cr hrs
CHEM 554, 555 (Proposal Writing)	3 cr hrs
CHEM 595 (Dissertation)	24 cr hrs

Students may substitute up to 6 credit hours of courses at the 300-level and above from other departments. Additional 500-level courses from other departments may be used in place of 500-level chemistry courses, upon approval of student's advisory committee.

Prior Master's Degree in Chemistry

A minimum of 38 credit hours is required. These hours are distributed as follows:

500-level chemistry courses	9 cr hrs minimum
CHEM 529, 530 (Seminar)	2 cr hrs
CHEM 554, 555 (Proposal Writing)	3 cr hrs
CHEM 595 (Dissertation)	24 cr hrs

Students may substitute up to 3 credit hours of courses at the 300-level and above from other departments. Additional 500-level courses from other departments may be used in place of 500-level chemistry courses, upon approval of student's advisory committee.

Chemistry Courses:

CHEM 109, Introduction to Chemistry, 3 cr, 2 cl hrs, 4 lab hrs

Prerequisite: MATH 101

Offered Fall Semesters

An overview of the fundamental concepts in chemistry. Topics will include a discussion of the classification of matter, the fundamental laws of chemical combination, the atomic theory and chemical bonding. The stoichiometry of chemical reactions will be presented. Several types of chemical reactions will be discussed, including precipitation reactions, oxidation-reduction reactions and acid-base reactions. Topics in organic and biochemistry will also be considered. Lectures will include numerous examples and demonstrations of chemical principles. Extensive laboratory exercises will further illustrate concepts discussed during the lecture hours.

CHEM 121, General Chemistry I, 3 cr, 3 cl hrs, 1.5 recitation hours

Prerequisite: MATH 103 (or equivalent, passed with grade C- or better) or CHEM 109 (passed with C- or better)

Corequisite: CHEM 121L

Offered fall and spring semesters

Basic descriptive and quantitative principles of chemistry associated with the concepts of the mole, concentration, heat, atomic and molecular structure, periodicity, bonding, physical states, stoichiometry, and reactions. [NMCCNS CHEM 1214: General Education Area III]

CHEM 121L, General Chemistry Laboratory I, 1 cr, 3 lab hrs

Corequisite: CHEM 121; a lab usage fee is charged

Offered fall and spring semesters

Laboratory experiments and techniques emphasizing principles from CHEM 121. [NMCCNS CHEM 1214: General Education Area III]

CHEM 122, General Chemistry II, 3 cr, 3 cl hrs, 1.5 recitation hours

Prerequisites: CHEM 121 and 121L

Corequisites: CHEM 122L and MATH 131 or equivalent

Offered fall and spring semesters

Continuation of CHEM 121. Emphasizes basic kinetics, thermodynamics, equilibria, electrochemistry, reactions of inorganic compounds, and an introduction to organic chemistry. [NMCCNS CHEM 1224: General Education Area III]

CHEM 122L, General Chemistry Laboratory II, 1 cr, 3 lab hrs

Corequisite: CHEM 122; a lab usage fee is charged

Offered fall and spring semesters

Laboratory experiments and techniques emphasizing principles from CHEM 122. [NMCCNS CHEM 1224: General Education Area III]

CHEM 151, General Chemistry I, 3 cr, 3 cl hrs

Prerequisite: MATH 103 (or equivalent, passed with grade C- or better)

Corequisite: CHEM 151L

Offered fall semester

Topic coverage parallels CHEM 121 with emphasis on critical thinking and active, collaborative and problem-based learning. Small class size, limited enrollment. Admission to this course involves a selection process. Contact the Chemistry Department (chem@nmt.edu) for details. Recommended for Chemistry majors; other majors are welcome. (The CHEM 151/152 sequence is equivalent to CHEM 121/122.)

CHEM 151L, General Chemistry I, 1 cr, 3 lab hrs

Corequisite: CHEM 151, a lab usage fee is charged

Offered fall semester

Laboratory experiments emphasizing principles from CHEM 151.

CHEM 152, General Chemistry II, 3 cr, 3 cl hrs

Prerequisite: CHEM 151 and 151L

Corequisites: CHEM 152 L and MATH 131 or equivalent

Offered spring semester

Continuation of CHEM 151. Topic coverage parallels CHEM 122 with emphasis on critical thinking and active, collaborative and problem-based learning. Small class size, limited enrollment. Admission to this course involves a selection process. Contact the Chemistry Department (chem@nmt.edu) for details. Recommended for Chemistry majors; other majors are welcome. The CHEM 151/152 sequence is equivalent to CHEM 121/122.)

CHEM 152L, General Chemistry Laboratory II, 1 cr, 3 lab hrs

Corequisite: CHEM 152, a lab usage fee is charged

Offered spring semester

Laboratory experiments emphasizing principles from CHEM 152.

CHEM 311, Quantitative Analysis, 3 cr, 3 cl hrs

Prerequisite: CHEM 122 passed with grade C- or better

Offered fall semester; offered spring semester if sufficient demand

Fundamental theory and techniques in traditional chemical analysis. Emphasizes sampling and separation methods, measurement, statistics, volumetric and gravimetric analysis, equilibrium and pH studies, basic electrochemical techniques, and introduction to instrumentation.

CHEM 311L, Quantitative Analysis Laboratory, 1 cr, 3 lab hrs

Corequisite: CHEM 311; a lab usage fee is charged.

Offered fall semester; offered spring semester if sufficient demand

Laboratory experiments and techniques emphasizing the principles from CHEM 311.

CHEM 331, Physical Chemistry I, 3 cr, 3 cl hrs

Prerequisites: CHEM 122 passed with grade C- or better; MATH 132; PHYS 122

Offered fall semester; offered spring semester if sufficient demand

Study of the fundamental principles of thermodynamics applied to equilibria, physical states, electromotive force, solution phenomena, and reaction kinetics. Study of physical state properties.

CHEM 331L, Physical Chemistry Laboratory I, 1 cr, 3 lab hrs

Corequisite: CHEM 331; a lab usage fee is charged

Offered fall semester; offered spring semester if sufficient demand

Laboratory experiments and techniques emphasizing principles from CHEM 331.

CHEM 332, Physical Chemistry II, 3 cr, 3 cl hrs

Prerequisite: CHEM 331

Offered spring semester

Atomic and molecular quantum theory, group theory, spectroscopy, and statistical mechanics.

CHEM 332L, Physical Chemistry Laboratory II, 1 cr, 3 lab hrs

Corequisite: CHEM 332; a lab usage fee is charged

Offered spring semester

Laboratory experiments and techniques emphasizing principles from CHEM 332.

CHEM 333, Organic Chemistry I, 3 cr, 3 cl hrs

Prerequisite: CHEM 122 passed with grade C- or better

Offered fall semester; offered spring semester if sufficient demand

Nomenclature, properties, structure, reactions, and synthesis of carbon compounds.

CHEM 333L, Organic Chemistry Laboratory I, 1 cr, 3 lab hrs

Corequisite: CHEM 333; a lab usage fee is charged

Offered fall semester; offered spring semester if sufficient demand

CHEM 334, Organic Chemistry II, 3 cr, 3 cl hrs

Prerequisite: CHEM 333

Offered spring semester

Continuation of CHEM 333.

CHEM 334L, Organic Chemistry Laboratory II, 1 cr, 3 lab hrs

Prerequisite: CHEM 333L

Corequisite: CHEM 334; a lab usage fee is charged

Offered spring semester

CHEM 411, Advanced Instrumental Methods, 3 cr, 3 cl hrs

Prerequisites: CHEM 311 and 332 or consent of instructor

Corequisite: CHEM 411L

Offered fall semester

Advanced techniques of chemical analysis. Emphasizes gas and liquid chromatography; electrochemistry; atomic spectrometry; ultraviolet, visible, and infrared spectroscopy; nuclear magnetic resonance spectroscopy; mass spectroscopy, etc.

CHEM 411L, Advanced Instrumental Laboratory, 1 cr, 3 lab hrs

Corequisite: CHEM 411; a lab usage fee is charged

Offered fall semester

Laboratory experiments and instrumental techniques emphasizing principles from CHEM 411.

CHEM 412, Advanced Topics in Analytical Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 311, 411, or consent of instructor

Offered on sufficient demand

Study of special topics not otherwise treated in analytical chemistry. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 512, with additional expectations for graduate credit.

CHEM 413, Separation Science, 3 cr, 3 cl hrs

Prerequisite: CHEM 331, 411, or consent of instructor

Offered on sufficient demand

Theory and practice of separation science. Topics include selective mass transport, extraction, chromatography, and electrophoresis. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 513, with additional expectations for graduate credit.

CHEM 422, Environmental Chemistry, 3 cr, 3 cl hrs

Prerequisites: Any two of the following: CHEM 311, 331, or 333 (or consent of instructor)

Offered Spring semester, even years

Application of chemical principles to the study of the environment. Includes natural processes and pollution problems related to water, air, and soil. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 522, with additional expectations for graduate credit.

CHEM 422L, Environmental Chemistry Laboratory, 1 cr, 3 lab hrs

Corequisite: CHEM 422/522; a lab usage fee is charged

Offered Spring semester, even years

Laboratory experiments related to the principles in CHEM 422/522. The graduate and undergraduate versions of the course will differ in the assignments and exams. Shares lab with CHEM 522L, with additional expectations for graduate credit.

CHEM 423, Applied Spectroscopy, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or consent of instructor

Offered on sufficient demand

Discussions of mass spectrometry, fluorescence, Nuclear Magnetic Resonance (NMR), X-ray (XPS, X-ray diffraction, solid state spectroscopy), Infrared (IR), Ultraviolet/Visible spectroscopic methods and techniques, as applied to chemical and biological problems, including structure elucidation, medical diagnostics, molecular sensors. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 523, with additional expectations for graduate credit.

CHEM 425, Molecular Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or consent of instructor

Offered on sufficient demand

Molecular structure; theories of the chemical bond; perturbation and variation methods; electronic and magnetic properties of molecules. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 525, with additional expectations for graduate credit.

CHEM 426, Chemical Spectroscopy, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or consent of instructor

Offered on sufficient demand

Principles and applications of electronic, molecular, and spin spectroscopies, laser spectroscopy; transitions; elements of group theory; quantitative correlations and analytical chemistry. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 523, with additional expectations for graduate credit.

CHEM 427, Molecular Reaction Dynamics, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or consent of instructor

Offered on sufficient demand

Techniques in studies of chemical reaction rates. Topics commonly include: rate laws, collision theory, mechanistic studies, transition state theory, fast reactions, chemical oscillations, transport theory, and transport coefficients. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 527, with additional expectations for graduate credit.

CHEM 428, Advanced Topics in Physical Chemistry

Prerequisite: CHEM 332 or consent of instructor

Offered on sufficient demand

Study of special topics not otherwise covered in physical chemistry. Shares lecture with CHEM 528, with additional expectations for graduate credit.

CHEM 431, Chemistry of Aquatic Systems, 3 cr, 3 cl hrs

Prerequisite: CHEM 311 or consent of instructor

Offered on sufficient demand

The thermodynamics and aqueous chemistry of natural waters, with emphasis on groundwater. Chemical equilibrium concepts, surface chemistry, redox reactions, and biochemistry. The interaction of water with the atmosphere and geologic materials. Basic concepts applied to problems of groundwater quality evolution, water use, and groundwater contamination. Shares lecture with CHEM 531, HYD 507 and GEOC 507 with additional expectations for graduate credit. (Same as EARTH 407.)

CHEM 432, Atmospheric Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 331, or consent of instructor

Chemistry of the atmosphere. Important chemical reactions and their effects on air, soil, and surface waters. Effects of anthropogenic inputs on the atmosphere, climate change. Distribution of chemical species in the atmosphere, etc. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 532, with additional expectations for graduate credit.

CHEM 433, Global Biogeochemical Cycles, 3 cr, 3 cl hrs

Prerequisite: CHEM 311 or 331, or consent of instructor

Offered on sufficient demand

Human activity is increasing the rate of addition of materials to the environment, resulting in changes to the earth's climate. The transformation and movement of natural and anthropogenic sources of chemical substances between reservoirs in a global context. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 533, with additional expectations for graduate credit.

CHEM 441, Biochemistry I, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or consent of instructor

Offered fall semester

Overview of basic biochemistry. Emphasizes structure, nomenclature, and reactions of biologically active compounds such as carbohydrates, lipids, proteins, nucleic acids, and enzymes. Introduction to metabolic pathways.

CHEM 441L, Biochemistry Laboratory I, 1 cr, 3 lab hrs

Corequisite: CHEM 441; a lab usage fee is charged

Offered fall semester

Experiments related to CHEM 441.

CHEM 442, Biochemistry II, 3 cr, 3 cl hrs

Prerequisite: CHEM 441

Offered spring semester

Continuation of CHEM 441. Emphasizes vertebrate biochemistry and the study of vitamins, hormones, biochemical genetics, and nutrition. Introduction to photosynthesis.

CHEM 442L, Biochemistry Laboratory II, 1 cr, 3 lab hrs

Corequisite: CHEM 442; a lab usage fee is charged

Offered spring semester

Topics related to CHEM 442.

CHEM 443, Intermediate Inorganic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 332

Offered spring semester

Atomic and molecular structure with relationships based on the periodic system; bonding theories; elements of group theory; chemistry in nonaqueous solvents; chemistry of the elements; coordination chemistry; ligand field theory.

CHEM 443L, Intermediate Inorganic Chemistry Laboratory, 1 cr, 3 lab hrs

Corequisite: CHEM 443; a lab usage fee is charged

Offered spring semester

CHEM 444, Advanced Topics in Organic Chemistry

Prerequisite: CHEM 333, 334, or consent of instructor

Offered on sufficient demand

Study of special topics not otherwise covered in organic chemistry. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 544, with additional expectations for graduate credit.

CHEM 445, Intermediate Organic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334

Corequisite: CHEM 445L

Offered on sufficient demand

The determination of the structure of organic compounds by chemical and physical means.

CHEM 445L, Intermediate Organic Chemistry Laboratory, 2 cr, 6 lab hrs

Corequisite: CHEM 445; a lab usage fee is charged

Offered on sufficient demand

CHEM 446, Polymer Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 and 334, or consent of instructor

Offered Fall Semesters, even years

Study of the preparation, properties, and uses of macromolecules. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 546, with additional expectations for graduate credit.

CHEM 447, Medicinal Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or consent of instructor

Molecular-level mechanisms of drug action and rational drug design. Material is drawn from the recent primary literature. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 547, with additional expectations for graduate credit.

CHEM 449, Organometallic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or consent of instructor

Organometallic chemistry of the main group and transition elements. Ligand classification and molecular orbital description of bonding in organometallic complexes. Structure, bonding, synthesis, and properties of transition metal compounds and their derivatives. Organometallic complexes as catalysts. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 549, with additional expectations for graduate credit.

CHEM 450, Physical Organic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or consent of instructor

Physical aspects of organic chemistry. Emphasizes reaction mechanisms, reaction kinetics, and electronic theories. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 550, with additional expectations for graduate credit.

CHEM 491, Special Problems, 1–3 cr**CHEM 493, Senior Research and Thesis, 1 cr**

Offered fall semester or on demand

Problem-oriented research under the direction of a faculty member. Students should consult with Chemistry faculty to find a Senior Thesis advisor. In the first semester, students will research a topic and begin work on the research project. Students are required to give a presentation and write a paper on the research topic.

CHEM 494, Senior Research and Thesis, 2 cr

Prerequisite: CHEM 493

Offered spring semester or on demand

Continuation the research begun in CHEM 493. Students are required to give a presentation and write a paper on their research project.

CHEM 495, Biomedical Senior Thesis I, 3 cr

For Biomedical Science majors. Mentored, problem-oriented biomedical research under the direction of a faculty member. Students should consult with their academic advisor and with various Chemistry faculty to identify a Thesis advisor. Near the end of the semester, students will give a formal research presentation.

CHEM 496, Biomedical Senior Thesis II, 3 cr

For Biomedical Science majors. Continuation of BIOL 495. Students are required to write a paper on the research project and to give an oral presentation.

All courses numbered 500 will be offered on sufficient demand, unless noted otherwise.

CHEM 500, Directed Research

This course may not be used to fulfill graduate degree requirements.

CHEM 501 Applied Molecular Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisites: CHEM 332, 334, and 443

Review of bonding, structure and symmetry. Application of molecular theory to contemporary problems in organic chemistry (e.g. EHMO, frontier orbital theory), inorganic chemistry (e.g. ligand field theory, Jahn-Teller effect) and analytical chemistry (e.g. photo physicochemical processes).

CHEM 512, Advanced Topics in Analytical Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 411 or consent of instructor

Study of special topics not otherwise treated in analytical chemistry. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 412, with additional expectations for graduate credit.

CHEM 513, Separation Science, 3 cr, 3 cl hrs

Prerequisite: CHEM 331 and 411, or consent of instructor

Theory and practice of separation science. Topics include selective mass transport, extraction, chromatography, and electrophoresis. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 413, with additional expectations for graduate credit.

CHEM 521, Advanced Topics in Biochemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 442 or consent of instructor

Study of special topics otherwise not covered in biochemistry.

CHEM 522, Environmental Chemistry, 3 cr, 3 cl hrs

Prerequisites: Any two of the following: CHEM 311, 331, or 333 (or consent of instructor)

Offered Spring semester, even years

Application of chemical principles to the study of the environment. Includes natural processes and pollution problems related to water, air, and soil. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 422, with additional expectations for graduate credit.

CHEM 522L, Environmental Chemistry Laboratory, 1 cr, 3 lab hrs

Corequisite: CHEM 422/522; a lab usage fee is charged

Offered Spring semester, even years

Laboratory experiments related to the principles in CHEM 422/522. The graduate and undergraduate versions of the course will differ in the assignments and exams. Shares lab with CHEM 422L, with additional expectations for graduate credit.

CHEM 523, Applied Spectroscopy, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or consent of instructor

Discussions of mass spectrometry, fluorescence, Nuclear Magnetic Resonance (NMR), X-ray (XPS, X-ray diffraction, solid state spectroscopy), Infrared (IR), Ultraviolet/Visible spectroscopic methods and techniques, as applied to chemical and biological problems, including structure elucidation, medical diagnostics, molecular sensors. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 423, with additional expectations for graduate credit.

CHEM 524 Statistical Thermodynamics, 3 cr, 3 cl hrs

Prerequisite: CHEM 331 or equivalent, or consent of instructor

Entropy, randomness, the Boltzmann distribution, and the chemical potential. Translational, rotational, vibrational, and electronic contributions to the partition function. Calculation of mean energies, heat capacities, and equilibrium constants. Stability. The influence of wave function symmetry: Bose-Einstein and Fermi-Dirac statistics. The quantum statistical operator. Coherence and the Pauli principle. (Same as Phys 508)

CHEM 525, Molecular Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or consent of instructor

Molecular structure; theories of the chemical bond; perturbation and variation methods; electronic and magnetic properties of molecules. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 425, with additional expectations for graduate credit.

CHEM 526, Chemical Spectroscopy, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or equivalent, or consent of instructor

Principles and applications of electronic, molecular, and spin spectroscopies, laser spectroscopy; transitions; elements of group theory; quantitative correlations and analytical chemistry. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 426, with additional expectations for graduate credit.

CHEM 527, Molecular Reaction Dynamics, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 or equivalent, or consent of instructor

Techniques in studies of chemical reaction rates. Topics commonly include: rate laws, collision theory, mechanistic studies, transition state theory, fast reactions, chemical oscillations, transport theory, and transport coefficients. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 427, with additional expectations for graduate credit.

CHEM 528, Advanced Topics in Physical Chemistry

Prerequisite: CHEM 331 and 332 or equivalent, or consent of instructor

Study of special topics not otherwise covered in physical chemistry. Shares lecture with CHEM 428, with additional expectations for graduate credit.

CHEM 529 (Fall), 530 (Spring), Graduate Seminar, 1 cr each semester

Offered Fall and Spring Semesters

All full time Chemistry graduate students must enroll in this course every fall and spring semester. Students giving a presentation must enroll for a letter grade. Other students should enroll using the S/U option.

CHEM 531, Chemistry of Aquatic Systems, 3 cr, 3 cl hrs

Prerequisite: CHEM 311 or consent of instructor

The thermodynamics and aqueous chemistry of natural waters, with emphasis on groundwater. Chemical equilibrium concepts, surface chemistry, redox reactions, and biochemistry. The interaction of water with the atmosphere and geologic materials. Basic concepts applied to problems of groundwater quality evolution, water use, and groundwater contamination. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 431, with additional expectations for graduate credit. (Same as GEOC 507 and HYD 507.)

CHEM 532, Atmospheric Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 331 or consent of instructor

Chemistry of the atmosphere. Important chemical reactions and their effects on air, soil, and surface waters. Effects of anthropogenic inputs on the atmosphere, climate change. Distribution of chemical species in the atmosphere, etc. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 432, with additional expectations for graduate credit.

CHEM 533, Global Biogeochemical Cycles, 3 cr, 3 cl hrs

Prerequisite: CHEM 311 or 331, or consent of instructor

Human activity is increasing the rate of addition of materials to the environment, resulting in changes to the earth's climate. The transformation and movement of natural and anthropogenic sources of chemical substances between reservoirs in a global context. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 433, with additional expectations for graduate credit.

CHEM 540, The Chemistry of Energetic Materials, 3 cr, 3 cl hrs

Prerequisite: CHEM 331 and 333, or consent of instructor

The chemistry of propellants, pyrotechnics, and explosives. Material to be covered will include history, oxidation/reduction reactivity, kinetics of decomposition, analytical characterization techniques, performance evaluation, hazards analysis, safety testing, and structure property relationships.

CHEM 543, Advanced Topics in Inorganic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 443 or equivalent, or consent of instructor

Study of special topics otherwise not covered in inorganic chemistry.

CHEM 544, Advanced Topics in Organic Chemistry

Prerequisite: CHEM 334 or equivalent, or consent of instructor

Study of special topics not otherwise covered in organic chemistry. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 444, with additional expectations for graduate credit.

CHEM 545, Advanced Organic Synthesis, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or equivalent, or consent of instructor

Principles and practices of organic synthesis.

CHEM 546, Polymer Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 332 and 334 or equivalent, or consent of instructor

Study of the preparation, properties, and uses of macromolecules. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 446, with additional expectations for graduate credit.

CHEM 547, Medicinal Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or equivalent, or consent of instructor

Molecular-level mechanisms of drug action and rational drug design. Material is drawn from the recent primary literature. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 447, with additional expectations for graduate credit.

CHEM 548, Experimental NMR Spectroscopy

Prerequisite: CHEM 334 or equivalent, or consent of instructor

A lab usage fee is charged

Introduction to NMR instrumentation, data-acquisition, and processing.

CHEM 549, Organometallic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or equivalent, or consent of instructor

Organometallic chemistry of the main group and transition elements. Ligand classification and molecular orbital description of bonding in organometallic complexes. Structure, bonding, synthesis, and properties of transition metal compounds and their derivatives. Organometallic complexes as catalysts. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 449, with additional expectations for graduate credit.

CHEM 550, Physical Organic Chemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 334 or equivalent, or consent of instructor

Physical aspects of organic chemistry. Emphasizes reaction mechanisms, reaction kinetics, and electronic theories. The graduate and undergraduate versions of the course will differ in the assignments and exams, while sharing the same lectures. Shares lecture with CHEM 450, with additional expectations for graduate credit.

CHEM 554/555, Research Proposal Writing, 3 cr, 3 cl hrs (1 cr 1st semester, 2 cr 2nd semester)

Students will choose a research topic, survey related literature and write an original research proposal in the first semester. In the second semester, the student will present a public seminar on the written proposal. Following the seminar, the student will defend the proposal to his or her dissertation or thesis committee. Both CHEM 554/555 will be offered concurrently in Fall and Spring semesters.

CHEM 581, Directed Study, cr to be arranged

Study under the guidance of a member of the faculty. A topic and schedule of meetings is arranged between instructor and student early in the semester.

CHEM 591, Thesis (master's program), cr to be arranged**CHEM 595, Dissertation (doctoral degree program), cr to be arranged**

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Faculty Research Interests

Altig—Computational Chemistry, Chemical Education
 Heagy—Organic Chemistry, Organic Synthesis, Physical Organic Chemistry
 Pias—Computational Chemistry and Biochemistry
 Piyasena—Bioanalytical Chemistry
 Tello Aburto—Organic Synthesis, Medicinal Chemistry
 Wingenter—Atmospheric and Ocean Chemistry, Climate Change
 Frolova—Organic and Medicinal Chemistry

Adjunct Faculty Research Interests

Clewitt—Nuclear Magnetic Resonance Spectroscopy
 Elliott—Ocean and Atmospheric Chemistry, Earth System Models
 Kalugin—Nanoscience, Optical and Electron Transport, Semiconductors, Optical and Infrared Spectroscopy
 Kirk—Physical Inorganic Chemistry, Bioinorganic Chemistry
 Kornienko—Organic and Medicinal Chemistry

Emeritus Faculty Research Interests

Brandvold—Biophysical Chemistry, Enzyme Mechanisms, Environmental Chemistry, Atmospheric Chemistry
 Brower—Physical Organic Chemistry, Explosives Chemistry
 Hatch—Organic Chemistry, Polymer Chemistry
 Popp—Environmental Chemistry, Geochemistry

Communication, Liberal Arts, Social Sciences (CLASS)

Professors Dezember, D. Dunston, S. Dunston, Lara-Martínez, Prusin

Associate Professor Simpson (Chair of the Department)

Assistant Professor Dotson, Durão, Kramer-Simpson

Instructors Griffin, Currie, Kieffer, Rowe, Stewart-Langley

Adjunct Faculty Henneke, Kurtz, López, Price

Emeritus Professors Campbell, Corey, Deming, Olsen, Wilson, Yee

Degree Offered: B.S. in Technical Communication, B.G.S., A.G.S.

Minors Offered: Hispanic Studies, History, Literature, Philosophy, Technical Communication

The multidisciplinary Department of Communication, Liberal Arts, and Social Sciences develops students' ability to learn, reason, and communicate in diverse fields of study and areas of human experience. The CLASS Department's mission is threefold: to help students write well, think critically, and read widely; to provide an intellectual experience that increases students' awareness of human history, human cultures, and human values; and to encourage the lifelong study of human experience.

The Department provides virtually all courses in three of the five areas of the General Education Core Curriculum required by the New Mexico Higher Education Department for the comprehensive education of undergraduates enrolled in New Mexico state institutions of higher education.

These areas are:

Area 1 — Communications (College Writing and Public Speaking);

Area 4 — Social Sciences (Cultural Anthropology, Political Science, Women's and Gender Studies);

Area 5 — Humanities/Liberal Arts (Art History, Communication, Creative Writing, Hispanic History, History, Languages, Literature, Media Studies, Music, Philosophy, Popular Culture, Technical Communication, Visual Art).

The Department offers three degrees: an industry-endorsed Bachelor of Science in Technical Communication, a Bachelor of General Studies, an Associate of General Studies, a graduate Certificate in Scientific and Professional Communication, and several minors, allowing students to enrich their studies at Tech to become successful professionals and knowledgeable members of society.

Degrees and Curricula: Bachelor of Science in Technical Communication

The Technical Communication curriculum combines courses from three fields of study to prepare students for technical communication positions upon graduation:

- The TC courses introduce students to document design, graphics, and computer documentation, created online and for multimedia. The TC courses also develop students' writing, speaking, and editing abilities.
- The humanities and social science courses improve students' understanding and appreciation of history, literature, philosophy, psychology, and the arts.
- The science and technology courses provide students a background in one specific science or engineering discipline.

Minimum credit hours required — 132

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- Technical Communication—35 credit hours of technical communication courses including TC 100 (1), 101 (1), 151 (3), 202 (3), 211 (3), 321 (3), 411 (3), 420 (3), 421 (3), 422 (3), and nine credit hours of technical communication electives. MGT 330 is an approved TC elective. All technical communication courses must be completed with grade C or better. Students may use these TC courses to fulfill Area 5 of the General Education Core Curriculum Requirements (page 7) with the exception of TC 321, TC 421, and TC 422.
- Humanities: 12 credit hours in excess of the General Education Core Curriculum Requirements and excluding TC courses.
- Foreign Language: Six credit hours of one language
- Science or Engineering: 12 credit hours in a single discipline in excess of general degree requirements
- Electives to complete 132 hours

Sample Curriculum for the Bachelor of Science in Technical Communication

Semester 1

- 1 TC 101 (orientation)
- 3 ENGL 111 (college English)
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 3 Foreign Language
- 15 Total credit hours

Semester 2

3	TC 151 (visual communication)
3	ENGL 112 (college English)
4	MATH 132 (calculus)
4	CHEM 122 & 122L (general)
<u>3</u>	Foreign Language
17	Total credit hours

Semester 3

3	TC 202 (elements of editing)
5	PHYS 121 & 121L (general)
3	Humanities
3	Social Science
<u>1</u>	Elective
15	Total credit hours

Semester 4

3	TC 211 (media studies)
5	PHYS 122 & 122L (general)
3	Humanities
3	Social Science
<u>1</u>	Elective
15	Total credit hours

Semester 5

1	TC 100 (community service)
3	ENGL 341 (technical writing)
6	Humanities
3	Humanities/Social Science
<u>3</u>	Science or Engineering
16	Total credit hours

Semester 6

3	TC 421 (professional writing workshop)
3	Technical Communication Elective
6	Humanities
3	Social Science
<u>3</u>	Science or Engineering
18	Total credit hours

Semester 7

3	TC 321 (internship)
3	TC 411 (persuasive writing)
3	TC 420 (senior seminar)
3	TC Elective
<u>3</u>	Science or Engineering
15	Total credit hours

Semester 8

3	Technical Communication Elective
3	TC 422 (senior thesis)
3	Science or Engineering
<u>6</u>	Electives
15	Total credit hours

Bachelor of General Studies*Minimum credit hours required—130*

This degree allows a student to plan a program of courses according to individual educational goals and career plans. The Bachelor of General Studies degree will be awarded after completion of 130 credit hours with a grade-point average of 2.0 or more. Other requirements for this degree include the following:

- Completion of the General Education Core Curriculum listed below.
- 42 credit hours in courses numbered 300 or above.
- Completion of the BGS Academic Career Plan with a stated Emphasis area or areas.
- Fulfillment of the Institution's residence credit requirement (30 credit hours).
- To be admitted into the program for this degree, the candidate must meet with the CLASS department chair and the BGS academic advisor, who will be assigned by the CLASS department chair, to create a BGS Academic Career Plan that will be on file with the Registrar. Any changes to the BGS Academic Career Plan must be approved by the CLASS department chair and the student's BGS academic advisor. These changes will be on file with the Registrar and must be met, along with the above-stated requirements, before the degree will be awarded.

General Education Core Curriculum for the Bachelor of General Studies (BGS)

Area 1: Communications (9 credit hours)

- ENGL 111 — ENGL 111 is waived for students who scored 27 or higher on the ACT English Test or 610 or higher on the SAT Critical Reading Test. These students must take ENGL 112, ENGL 242 and ENGL 341 to fulfill the 9 credit hours in this area.
- ENGL 112
- COMM 242 or ENGL 341

Area 2: Mathematics (3 credit hours)

- MATH 101
- MATH 103
- MATH 104
- MATH 105
- MATH 131

Area 3: Laboratory Sciences (8 credit hours with associated labs)

- BIOL 111 & Lab
- BIOL 112 & Lab
- CHEM 109
- CHEM 121 & Lab
- CHEM 122 & Lab
- PHYS 121 & Lab
- PHYS 122 & Lab
- ES 110 & Lab

- ES 111 & Lab
- CSE 113
- Engineering with lab (ChE, CE, EE, ENVE, MATE, METE, ES, MENG, ME, PETR)

Area 4: Social Sciences (6 credit hours)

- Anthropology (ANTH)
- Economics (ECON)
- Political Science (PS)
- Psychology (PSY)
- Social Sciences (SS)
- Women's and Gender Studies (WGS)

Area 5: Humanities (6 credit hours)

- English (ENGL), except 103, 111, 112, 341. If ENGL 242 is used to fulfill credits in Area 1, it cannot also count in Area 5.
- Art History (ART)
- History (HIST)
- Humanities (HUMA)
- Music (MUS) except for performance ensembles
- Technical Communication (TC) except TC 321, 420, 422
- Foreign Languages (SPAN, FREN, GERM). Other languages may be counted only if they are listed or approved by the CLASS Department.

Area 6: Additional Courses from Area 4 or Area 5 (6 credit hours)

NOTE: Students who plan to pursue a career or graduate studies that require a Bachelor of Science degree are advised to pursue another degree program at New Mexico Tech.

Associate of General Studies

Minimum credit hours required—65

A two-year certificate, Associate of General Studies, may be awarded after completion of 65 credit hours of course work approved by the CLASS department chair and the student's AGS academic advisor with a grade-point average of 2.0 or above. Fulfillment of the Institution's residence requirement (30 credit hours) must also be met.

- To be admitted into the program for this degree, the candidate must meet with the CLASS department chair and the AGS academic advisor, who will be assigned by the CLASS department chair, to create a AGS Academic Career Plan that will be on file with the Registrar.
- Any changes to the AGS Academic Career Plan must be approved by the CLASS department chair and the student's AGS academic advisor. These changes will be on file with the Registrar. The certificate will be awarded only after completion of the above requirements and completion of the AGS academic Career Plan and after petition to the Vice President for Academic Affairs.

- Completion of the General Education Core Curriculum listed below.

General Education Core Curriculum for the Associate of General Studies (AGS)

Area 1: Communications (9 credit hours)

- ENGL 111 — ENGL 111 is waived for students who scored 27 or higher on the ACT English Test or 610 or higher on the SAT Critical Reading Test. These students must take ENGL 112, ENGL 242 and ENGL 341 to fulfill the 9 credit hours in this area.
- ENGL 112
- COMM 242 or ENGL 341

Area 2: Mathematics (3 credit hours)

- MATH 101
- MATH 103
- MATH 104
- MATH 105
- MATH 131

Area 3: Laboratory Sciences (8 credit hours with associated labs)

- BIOL 111 & Lab
- BIOL 112 & Lab
- CHEM 109
- CHEM 121 & Lab
- CHEM 122 & Lab
- PHYS 121 & Lab
- PHYS 122 & Lab
- ES 110 & Lab
- ES 111 & Lab
- CSE 113
- Engineering with lab (ChE, CE, EE, ENVE, MATE, METE, ES, MENG, ME, PETR)

Area 4: Social Sciences (6 credit hours)

- Anthropology (ANTH)
- Economics (ECON)
- Political Science (PS)
- Psychology (PSY)
- Social Sciences (SS)
- Women's and Gender Studies (WGS)

Area 5: Humanities (6 credit hours)

- English (ENGL), except 103, 111, 112, 341. If ENGL 242 is used to fulfill credits in Area 1, it cannot also count in Area 5.
- Art History (ART)
- History (HIST)
- Humanities (HUMA)
- Music (MUS) except for performance ensembles
- Technical Communication (TC) except TC 321, 420, 422

- Foreign Languages (SPAN, FREN, GERM). Other languages may be counted only if they are listed or approved by the CLASS Department.

Area 6: Additional Courses from Area 4 or Area 5 (6 credit hours)

Graduate Certificate in Scientific and Professional Communication

Minimum credit hours required—18

The Scientific and Professional Communication Graduate Certificate offers graduate students and post-baccalaureate professionals an opportunity to build and strengthen their professional communication abilities for academic and professional work. The 18 hours of coursework required for the Certificate brings the student from a general foundation (ENGL 501 and TC 511) to specific media of presentation (COMM 560), while elective courses are available to students with specific interests; for example professionals who work in the Americas will benefit from SPAN 520, engineers may be interested in a course specifically designed for Engineering Communication (COMM 570).

Requirements for this degree include the following:

- ENGL 501 (3), TC 505 (3), TC 511 (3), COMM 560 (3)
- Six credits from the following: ENGL 511 (3), COMM 570 (3), COMM 575 (3), PHIL 521 (3), SPAN 520 (3), TC 512 (3), TC 521 (3), TC 561 (3), TC 589(3)

Students must be concurrently enrolled in a graduate degree program at NMT or meet the admissions criteria to enroll in a graduate degree program (including as special graduate students).

Minors

The CLASS Department offers several minors to explore a field of study in more detail.

All Minors

- *Minimum credit hours required—18*
- *Restriction: If a student takes more than one minor in the CLASS Department, only six (6) credit hours of one minor may be applied towards another minor.*
- *Additional requirements as listed under each minor.*

Minor in Hispanic Studies

The following courses are required:

- One of the following sequences (6)
 - SPAN 113 and 114, Elementary Spanish I and II
 - SPAN 113N and 114N, Spanish for Native

Speakers

- An additional 12 credit hours in any topic relevant to Hispanic Studies with the consent of the minor advisor

Minor in History

The following courses are required:

- A 100-level history course sequence (6)
- Twelve (12) additional credit hours in history courses. Of these 12 credit hours, six (6) credit hours may be taken in art history or music surveys
- Students taking the history minor are strongly encouraged to take the 12 additional credit hours from as wide a variety of topics as possible.

Minor in Literature

The following courses are required:

- 18 credit hours in ENGL literature courses

Minor in Philosophy

The following courses are required:

- PHIL 231, Comparative Introduction to Western Philosophy
- Fifteen (15) additional credit hours in philosophy courses.
- With the consent of the minor advisor, of these 15 credit hours, six (6) credit hours may be taken in upper-division courses that have a substantial philosophical focus and content.

Minor in Technical Communication

The following courses are required:

- TC 151 (3)
- TC 202 (3)
- TC 211 (3)
- Nine (9) additional credit hours of TC courses

General Education Core Curriculum Information

The courses offered through the CLASS Department fulfill four areas (Area 1, 4, 5, and 6) required for the Bachelor of Science. Additional Social Sciences are offered through the Psychology Department (PSY courses) and the Management Department (ECON courses).

Area 1 - Communications	ENGL 103, 111, 112, 341
Area 4 - Social Sciences	ANTH Anthropology PS Political Science SS Social Science WGS Women's and Gender Studies
Area 5 - Humanities	ART Art History COMM Communication ENGL English (except ENGL 103, 111, 112, 341) FREN French GERM German HIST History HUMA Humanities MUS Music (except Performance Ensembles) PHIL Philosophy SPAN Spanish TC Technical Communication (except TC 321, 420, 422)
Area 6	Additional Courses from Area 4 or 5

Anthropology Courses:

The following courses may be used to fulfill Area 4: Social Sciences of the General Education Core Curriculum (page 7).

ANTH 101, Introduction to Cultural Anthropology, 3 cr, 3 cl hr

An introduction to the science of cultural Anthropology, its terminology, theory practice and subject matter. Students are encouraged to engage with other cultures to find similarities and connections, not differences and separation. Studies human beings, their social and cultural institutions, beliefs, and practices around the world and next door, creating a medley of adaptations to common problems.

ANTH 120, Social Thought, 3 cr, 3 cl hr

From Machiavelli and Marx to Steinem and Foucault, this course explores some of the major historical and contemporary theoretical works and authors in selected social sciences. The focus is on the cultural framework in which these thoughts emerged and the impact they had on society. (Same as WGS 120 and SS 120)

ANTH 302, Food and Culture, 3 cr, 3 cl hr

Food is more than just nutrition; in every culture, past and present, food is central to building and maintaining economic and political systems, social relationships among family members and between friends and enemies, religious taboos, ethnic identities, and gender norms. The trade in food stuffs is at the heart of colonization and globalization; the lack of food is at the heart of labor migrations and horrors of malnutrition and starvations; and the science of food causes biogenetic engineering to choose between creating profit for some or life for many. This class examines these issues, ranging from seemingly universal meals to mass-produced hamburgers, and counting the human, animal, and environmental costs of each.

ANTH 303, Race and Ethnic Relations, 3 cr, 3 cl hrs

An overview of most "racial" and ethnic groups of Americans. Provides a theoretical framework to explore their histories and critical current issues and a space to enjoy the advantages of a multicultural philosophy. Focuses on the heterogeneous character of all ethnic groups, especially in regard to gender and class; attempts to define common issues that can only be solved in unison.

ANTH 320, Anthropology of Sex and Gender, 3 cr, 3 cl hrs

A survey of the varieties of sex and gender definitions and roles in historical and contemporary human cultures. The study of sex assignment, gender definitions and roles in their association to stratified or equitable access to economic, political, and ideological resources and monopolies. Exploration of the parallels and differences between gender, race, and class. Topics include: gendered division of labor, female and male socialization, violence against women as male entertainment and female punishment, gender universals and generalities. (Same as WGS 320.)

ANTH 370, Nahuatl Mythology & Anthropology, 3 cr, 3 cl hr

A study of Native language, literature, and mythology of Central America. The class explores a specific native literature in its own language and discusses an "American" worldview. Topics include the concept of a fragmented self and of multiple souls, of political community and redistribution, a quintesimal (5) and vigesimal (20) system of counting, sexuality, and the foundation of a Native philosophy. (Same as SPAN 370)

ANTH 381, Qualitative Methods, 3 cr, 3 cl hr

An introduction to the primary methods used in long-term qualitative data gathering, such as participant observation and deep ethnography, and in short-term applied data collection, such as focus groups and life histories. A major focus is research conducted with organizations and their culture. Students will design and execute their own research projects. (Same as WGS 381 and TC 381)

Art History Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

ART 272, Art History, 3 cr, 3 cl hrs

Survey of art of the western hemisphere from prehistory to the 21st century. May incorporate an interdisciplinary approach. [NMCCNS ARTS 2113: General Education Area V]

ART 372, Issues in Art History, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Issues, topics, or specific periods in the visual arts. May incorporate an interdisciplinary approach. Topics may include, among others, Visual and Other Arts; Modern Art; Art and Science; Literature inspired by Art; Modern Art, Sci Fi, and Film.

Communication Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

COMM 242, Public Speaking, 3 cr, 3 cl hrs

A study of the principles of speech; practice in the preparation and delivery of various types of speeches, classified according to function; practice in the basic skills of oral communication; the development of poise and self-confidence. [NMCCNS COMM 1113: General Education Area I]

COMM 360, Advanced Public Speaking, 3 cr, 3 cl hrs

Prerequisites: COMM 242 or consent of instructor

Theory and practice of ethical and professional speech communication. Researching, writing and presenting professional presentations. Designing and using effective visuals, including posters and electronic presentation aids. Conducting group presentations and discussions about ethical and cross-curriculum issues in historical, cultural and workplace context.

COMM 560, Professional Public Speaking, 3 cr, 3 cl hrs

Prerequisites: Consent of instructor

Theory and practice of ethical and professional speech communication. Research, writing and presenting professional presentations. Designing and using effective visuals, including posters and electronic presentation aids. Conducting group presentations and discussions about ethical and cross-curriculum issues in historical, cultural and workplace context. Design, schedule and present a formal research colloquium.

COMM 570, Communication in Engineering, 3 cr, 3 cl hrs

Prerequisites: Graduate Enrollment in Engineering

Advanced communication/writing courses linked to engineering disciplines, focusing on graduate and professional genres (e.g., conference abstracts, journal articles, and conference presentations). Emphasis on communicating technical information to a variety of audiences.

COMM 575, Communication in the Sciences 3 cr, 3 cl hrs

Prerequisites: Graduate Enrollment in Sciences

Advanced communication/writing courses linked to science disciplines, focusing on graduate and professional genres (e.g., conference abstracts, journal articles, and conference presentations). Emphasis on communicating technical information to a variety of audiences.

COMM 580, Thesis & Dissertation Boot Camp 1 cr

Boot Camp is a weeklong, intensive course on thesis-writing. Students receive short workshops on time-management and project planning, strategies for overcoming writer's block, peer review, and graduate school thesis requirements (e.g., formatting, copyright, etc.). Additionally, students spend 5-6 hours a day in a distraction-free writing environment and have opportunities for feedback from the instructor or available writing consultants.

English Courses:

The following courses (except ENGL 103, 105, 111, 112, 305, 315, 341) may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

Writing Program Courses:

ENGL 103, Pre-College English, 3 cr, 3 cl hrs

The basics of writing: sentence types, structure, and construction; topic sentences, paragraph development and coherence; the complete essay; grammar, usage, and punctuation. Prepares students for ENGL 111. (*Does not fulfill the English portion of the General Education Core Curriculum, page 7.*)

ENGL 105, Introductory Academic Communication, 1 cr, 1 cl hr

The course introduces students to the general culture of a US university and provides opportunities to discuss language-related issues in their coursework (e.g., understanding lectures, communicating with professors and TAs, etc.). Students are also introduced to strategies for drafting and editing academic writing and for preparing and giving academic presentations.

ENGL 111, College Writing: Exposition, 3 cr, 3 cl hrs

The essentials of academic prose; techniques and mechanics of writing well; rhetorical strategies. [NMCCNS ENGL 1113: General Education Area I]

ENGL 112, College Writing: Argument and Analysis, 3 cr, 3 cl hrs

Prerequisite: ENGL 111 or equivalent course passed with a C or better

A continuation of ENGL 111 with critical reading and writing; writing arguments; library research paper. [NMCCNS ENGL 1123: General Education Area I]

ENGL 305, Communication for Multilingual Students, 1 cr, 1 cl hr

Prerequisite: At least junior standing or consent of instructor

Students work on reading and responding to academic texts in English; crafting and expressing an original argument on an academic topic; and correctly summarizing, paraphrasing, and citing academic texts. Students will write and present on topics in their fields of study, provide constructive feedback on each other's work, and practice articulating and answering questions on academic topics.

ENGL 315, Academic and Scientific Communication for Multilingual Students, 3 cr, 3 cl hrs

Prerequisite: At least junior standing

This course offers a more advanced introduction to language issues in writing for scientific and technical fields. Students in this class explore language use and academic genres in their fields of study and complete an extended research project on a technical topic. The course culminates in a technical research report and conference-style presentation.

ENGL 341, 341D, Technical Writing, 3 cr, 3 cl hrs

Prerequisites: ENGL 111 and 112 or the equivalent passed with a grade C or better and at least junior standing

This course emphasizes clear, accurate, and precise communication and scientific and technical information to a variety of audiences, for a variety of purposes. Students will be taught how to effectively analyze the components of writing situations and appropriately conduct research, write content in a professional, yet accessible style, incorporate visuals, organize and format documents. The course culminates with a substantial technical research report and oral presentation. In addition, students work on writing documents including memos, proposals, short reports, and instructions.

ENGL 501, Graduate Writing Seminar, 3 cr, 3 cl hrs

Prerequisite: Proficiency in written and spoken English, Graduate standing or consent of instructor

Intensive practice in academic writing for graduate students. Focuses on writing and revision. Reviews the history and development of science writing and surveys the professional environments in which scientists are expected to publish. Students should come with a draft of a substantial piece of work—such as an article, chapter, or grant proposal.

ENGL 511, Graduate Creative Writing, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Professional-level writing in fiction, poetry, creative non-fiction or plays. Focuses on the genre of the student's choice. Students write often, revise frequently, learn and apply methods of Creative Writing instruction.

Literature Courses:

ENGL 120, Introduction to Literature, 3 cr, 3 cl hrs

Survey of major works of poetry, short fiction, and drama in English and in translation. [NMCCNS ENGL 1013: General Education Area V]

ENGL 311, Creative Writing, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The study and writing of one genre or a combination of the following genres: poetry, fiction, creative nonfiction, playwriting and screenwriting. Emphasis on reading and analyzing literature.

ENGL 312, Short Fiction, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Concentrated study of major works of short fiction written in English and in translation.

ENGL 321, American Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

An historical survey of 17th, 18th, and 19th century writing, covering the Colonial, Enlightenment, and Romantic periods. Among the authors studied are Anne Bradstreet, Benjamin Franklin, Edgar Allan Poe, Nathaniel Hawthorne, and Emily Dickinson. [NMCCNS ENGL 2513: General Education Area V]

ENGL 322, American Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

An historical survey of 19th and 20th century writing, covering Realism and Naturalism and the Modern period. Among the authors studied are Mark Twain, Willa Cather, Robert Frost, Eugene O'Neill, Ernest Hemingway, William Faulkner, Katherine Anne Porter, and James Baldwin. [NMCCNS ENGL 2523: General Education Area V]

ENGL 323, American Nature Writing, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Survey of American nature Writers, such as Lewis and Clark, Thoreau, Edward Abbey, and Leslie Marmon Silko, with literary and philosophical analysis of their observational, documentary, rhetorical, inter-disciplinary, and self-reflective strategies to develop students' own skills in these areas and to produce their own nature writing. (Same as PHIL 323)

ENGL 324, Ecotopia: The Intersection of Science and Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Utopian Literature, whether Paradise myths or novels set on an idyllic island or in the future, chronicles human aspirations for a better society. Ecotopia—a neologism coined in 1968—combines utopian desires for better relationships between humans with more recent desires and need for a better relationship with the environment. The course provides a review of utopian literature throughout history and focuses on contemporary science fiction novels and developments in architecture, technology, science, and alternative social structures. Shares lecture with ENGL 524, with additional expectations for graduate credit.

ENGL 325, World Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Literature of the West from the Classics through the Renaissance. [NMCCNS ENGL 2613: General Education Area V]

ENGL 326, World Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Literature of the West from Neoclassicism to Contemporary. [NMCCNS ENGL 2623: General Education Area V]

ENGL 331, British Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

A survey of British literature from its origin through the Age of Enlightenment. Major authors studied include the Beowulf poet, Chaucer, Shakespeare, and Milton. [NMCCNS ENGL 2413: General Education Area V]

ENGL 332, British Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

A continuation of ENGL 331, this course surveys British literature of the nineteenth and twentieth centuries. Emphasis is upon the major literary movements of Romanticism and Realism. [NMCCNS ENGL 2423: General Education Area V]

ENGL 352, Contemporary Latin American Novel, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or equivalent

Survey of the 20th century Latin American regional novel. How contemporary writers have portrayed the Latin American continent: social-realism, surrealism, the boom, neo-baroque, magical realism, mestizaje, social-protest, negrismo, etc. Focus on reading classical works such as Arguedas, Asturias, Castellanos, Fuentes, Roa Bastos, Rulfo. (Same as Spanish 352)

ENGL 355, Latin American Fiction & the Arts, 3 cr, 3 cl hrs

A historical journey of a multi-cultural continent. Politics, economic disparity, military dictatorship, oppression and revolutionary resistance are studied through the lens of arts and literature. The most varied styles—social-realism, surrealism, fantasy, magical-realism, etc.—complement factual history to offer an accurate picture of a cruel social reality. (Same as SPAN 355)

ENGL 357, Latin American Literature, 3 cr, 3 cl hrs

A review of Latin American literary production with examples of its cultural and artistic diversity. The class examines the most important writers from Mexico, the Caribbean, Central America, the Andean region and the Southern cone, and relates their poetic legacy to the social sciences and philosophy. (Same as SPAN 357)

ENGL 431, Literary Genres, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The study of a particular type of literature, its origins, characteristics, subtypes, and some of its major writers and works. Possible genres are poetry, drama, short stories, science fiction, novels, and nonfiction writing. May be repeated for credit with different genres.

ENGL 435, Major Writers, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Intensive study of the writing of a major world author or authors, such as Willa Cather, Nathaniel Hawthorne, Herman Melville, William Shakespeare, Mark Twain. May be repeated for credit with different writers.

ENGL 436, Issues and Themes in Literature, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Concentrated study of issues, ideas, and themes as they affect or are embodied in literature. Possible topics include, among others, Environment, Gender, Ethnicity, Travel, and Place. May be repeated for credit with different issues.

ENGL 440, Philosophical Novels, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 and one PHIL course

Exploration of the use and articulation of philosophy in novels. (Same as Phil 440)

ENGL 491, Directed Studies, hrs and cr to be arranged

Prerequisite: ENGL 112 or consent of instructor

ENGL 511, Graduate Creative Writing, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Professional-level writing in fiction, poetry, creative non-fiction or plays. Focuses on the genre of the student's choice. Students write often, revise frequently, learn and apply methods of Creative Writing instruction.

ENGL 524, Ecotopia: The Intersection of Science and Literature, 3 cr, 3 cl hrs

Prerequisite: Graduate Standing or consent of instructor

Utopian Literature, whether Paradise myths or novels set on an idyllic island or in the future, chronicles human aspirations for a better society. Ecotopia—a neologism coined in 1968—combines utopian desires for better relationships between humans with more recent desires and need for a better relationship with the environment. The course provides a review of utopian literature throughout history and focuses on contemporary science fiction novels and developments in architecture, technology, science, and alternative social structures.

Shares lecture with ENGL 324, with additional expectations for graduate credit.

French Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

FREN 113, Elementary French I, 3 cr, 3 cl hrs

Elements of French, with particular emphasis on pronunciation, through conversational materials. Stress is placed on the fundamentals of French grammar, spelling, and written expression. Supplementary readings reinforce comprehension and give additional sources for spontaneous oral expression in class discussion. [NMCCNS FREN 1113: General Education Area V]

FREN 114, Elementary French II, 3 cr, 3 cl hrs

Prerequisite: FREN 113 or equivalent

Continuation of FREN 113. [NMCCNS FREN 1123: General Education Area V]

FREN 215, Intermediate French I, 3 cr, 3 cl hrs

Prerequisite: FREN 114 or equivalent

Introduction to literary passages of easy comprehension. Translation and practice of composition, with emphasis on oral performance in class. Review of grammar through exercises.

FREN 216, Intermediate French II, 3 cr, 3 cl hrs

Prerequisite: FREN 215 or equivalent

Continuation of FREN 215.

German Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

GERM 113, Elementary German I, 3 cr, 3 cl hrs

Elements of German, with emphasis on the spoken language. Grammar and composition are introduced in connection with the subjects of oral practice.

GERM 114, Elementary German II, 3 cr, 3 cl hrs

Prerequisite: GERM 113 or equivalent

Continuation of GERM 113.

GERM 211, Intermediate German I, 3 cr, 3 cl hrs

Prerequisite: GERM 114 or equivalent

Expansion of skills in German language through readings in German culture, conversation, and writing. Review of German grammar.

GERM 212, Intermediate German II, 3 cr, 3 cl hrs

Prerequisite: GERM 211 or equivalent

Continuation of GERM 211.

History Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

HIST 131, Western Civilization I 5000BC – 1500 AD, 3 cr, 3 cl hrs

Examines pivotal events in the history of the western world (primarily the European continent) from the early civilizations to the Renaissance. Explores the political, socio-economic, and cultural developments in the Fertile Crescent, ancient Greece and Rome, and medieval Europe. The course is organized in chronological and topical units, each within the framework of political geography, economy, religion, and culture.

HIST 132, Western Civilization II, 1500 AD – 2000, 3 cr, 3 cl hrs

Examines the political, social, economic, and cultural developments from the Reformation to the European Union. Explores the watersheds in European history that continue to shape modern politics and societies.

HIST 141, American History to 1865, 3 cr, 3 cl hrs

A survey of American history from pre-contact North America to the end of the Civil War. The social, cultural, intellectual, and political history of the American people. [NMCCNS HIST 1113: General Education Area V]

HIST 142, American History since 1865, 3 cr, 3 cl hrs

A continuation of HIST 141, with attention given to the rise of the United States as a world power, urbanization and industrialization, the role of the state, and civil rights movements. [NMCCNS HIST 1123: General Education Area V]

HIST 151, World History I, 3 cr, 3 cl hrs

The evolution of the major Eurasian civilizations from the beginning of historical times to the beginning of the 16th century, with special reference to social, political, and cultural developments.

HIST 152, World History II, 3 cr, 3 cl hrs

A continuation of HIST 151, emphasizing social, political, and cultural developments in Eurasian civilization from 1500 to the present.

HIST 161, Europe in the 19th Century, 1815-1914, 3 cr, 3 cl hrs

An introduction to the major developments and themes in nineteenth century European history, including major international developments such as the Congress System, the Revolutions of 1848, the advance of modern ideologies and major trends in arts and sciences, and the causes of World War I.

HIST 162, Europe in the 20th Century, 1914-2000, 3 cr, 3 cl hrs

Explores the great watersheds of the last century in Europe, from World War I to the fall of the USSR and the rise of the European Union. Several case-studies help students understand the legacy of the 20th century and the problems we face today.

HIST 334, The American West, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The history of the American West up to the present. Exploration and conquest, the movement of peoples, the role of the federal government, rural and urban development, resource use, issues of race and ethnicity, gender and class, as well as the “idea” of the West.

HIST 342, American Popular Culture, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The history of American popular culture, with primary focus on the twentieth century. Examines such subjects as film, television, music, and print media.

HIST 343, Atomic America: The Cultural History of Nuclear Technology in the United States, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The history of nuclear technology in the United States. Explores the cultural, social, political, and economic dimensions of atomic energy, with particular emphasis given to changing images in popular culture. May include guest speakers and field trips to the Trinity Site and the National Atomic Museum.

HIST 345, The Rise and Fall of the Soviet Union, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The Bolshevik Revolution, the development of Stalinist totalitarianism, reform under Khrushchev, the “stagnation” era of Brezhnev, and the end of the “great experiment” with Gorbachev.

HIST 348, War and Society, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

The political, economic, social, and ideological implications of warfare.

HIST 376, Mass Violence through the Ages, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

This course examines the nature and dynamics of mass violence and aggression, and their impact on politics and societies. Through lectures and readings, students explore and compare political, sociological and psychological dimensions of genocides, state terror, and ethnic cleansing.

HIST 380, Technology in America, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

The role technology has played in American history since colonial times, focusing on the relationship of technology to American culture and the changing role of technologies and technological systems in a modern industrial society.

HIST 385, Latin American Cultural History, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Overview of the cultural history of the Iberian world on both sides of the Atlantic from the earliest cultural expression to the current Hispanic presence in the United States. Multicultural creations of Hispanic societies. Cultural productions, i.e., fiestas, toreo, music, painting, literature, graffiti—in their political, economic, and historical background. (Same as SPAN 385)

HIST 386, Introduction to The Middle East, 3 cr, 3 cl hrs

Prerequisite: At least one 100-level history course or equivalent; ENGL 112

The course is a general introduction to the history of the area known as the Fertile Crescent, with a focus on the political, ethnic, religious, and socio-economic policies of the principal states of the region.

HIST 387, Eastern Europe in The 20th Century, 3 cr, 3 cl hrs

Prerequisite: At least one 100-level history course or equivalent; ENGL 112

The course explores major political, socio-economic, and cultural developments in the “Lands Between” - the Baltic States, Poland, Hungary, Czechoslovakia, Romania, Bulgaria, Yugoslavia, and Albania—with particular attention to politics, economics, and culture.

HIST 421, The Age of Radical Ideologies, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

The theory and practice of nationalism, anarchism, communism, and fascism in the 19th and 20th centuries.

HIST 448, The Cold War, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

Senior-level seminar examining the history of the Cold War.

HIST 466, Historical Fiction, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

This seminar explores the genre of historical fiction, examining several historical fiction novels and shorter works.

HIST 467, Film Genres, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

Writing intensive senior-level seminar. Examines a selected film genre (e.g. film noir, westerns, science fiction) in depth.

HIST 472, Special Topics, 3 cr, 3 cl hrs**HIST 491, Directed Studies, hrs and cr to be arranged**

Prerequisite: Senior standing or consent of instructor

Humanities Courses:

The following course may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

HUMA 301, Practical Creativity, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor.

May be applied by philosophy minors toward the requirement for 18 credit hours in philosophy.

An investigation of factors impacting creativity (discipline, time-pressure, constraints), conceptions of creativity (play, inspiration, complex adaptive systems), and applications of creativity (problem solving, negotiation, art).

HUMA 311, Shakespeare and Music, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor.

An interdisciplinary study of selected works of Shakespeare through a musical lens. Shakespeare’s plays were written to be spoken and heard, and this course explores the parallel issues of choice and constraint in the acts of speaking and hearing Shakespeare’s words, applying tools commonly used to facilitate the performance and reception of music.

HUMA 481, Capstone Seminar, 3 cr, 3 cl hrs

Prerequisites: Senior standing and must have completed at least 12 credit hours in Humanities/Social Science courses.

Topic varies. An interdisciplinary, team-taught, upper-division seminar. Students will examine the topic from a wide variety of perspectives and consider how it relates to their chosen field of study/profession. May include a final project that will be reviewed by an advisor from the student’s major department.

Music & Music Performance Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

MUS 105, Fundamentals of Music, 3 cr, 3 cl hrs

An introduction to the basic materials of music: tones, rhythm, notation, singing, and composition. [NMCCNS MUSI 1113: General Education Area V]

MUS 110, Music Appreciation, 3 cr, 3 cl hrs

A listening-intensive study of rhythm, melody, and musical structure in Western and other music from antiquity to the present. [NMCCNS MUSI 1113: General Education V]

MUS 201, Comprehensive Musicianship I, 3 cr, 3 cl hrs, 1 lab hr

Prerequisite: MUS 105 or consent of instructor

A detailed study of notation, keys, scales, intervals, chords, clefs, and transpositions. Practical application to keyboard, instruments, and voice.

MUS 301, Composition, 3 cr, 3 cl hrs

Prerequisite: ENGL 112

An introduction to the structural principles of music composition. Students will use software tools to study patterns in existing compositions and then create several computer-based compositions within specific design constraints. Final project compositions will be presented in public performance. Prior music background not required.

MUS 311, Opera, 3 cr, 3 cl hrs

Prerequisite: MUS 105, or consent of instructor

A musical and socio-historical exploration of selected great operatic works.

Music Performance Courses:

These courses are "offered on demand," i.e. when a sufficient number of students want to enroll, and they may be taken for elective credit only. These courses can be repeated for credit as determined by the instructor. These courses may NOT be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

MUS 171, 172, Beginning Group Voice, 1 cr, 2 cl hrs

Basic techniques of correct singing.

MUS 273, 274, Intermediate Group Voice, 1 cr, 1 cl hr

Prerequisite: MUS 171, 172, or consent of instructor

Development of personal vocal technique, musicianship, diction.

MUS 331–332, Chamber Choir, 1 cr, 2 cl hrs

Prerequisite: Consent of instructor

MUS 333–334, Concert Chorus, 1 cr, 2 cl hrs

The Concert Chorus performs large-scale choral works independently and together with the Chamber Orchestra. Interested students without prior singing experience are encouraged to participate.

MUS 341–342, Jazz Ensemble, 1 cr, 2 cl hrs

Prerequisite: Consent of instructor

MUS 351–352, Chamber Orchestra, 1 cr, 2 cl hrs

Prerequisite: Consent of instructor

MUS 361–362, Chamber Music, 1 cr, 1 cl hr

Prerequisite: Consent of instructor

MUS 377, 378, Vocal Performance, 1 cr, 1 cl hr

Prerequisite: MUS 273, 274, or consent of instructor

Practical and theoretical aspects of solo vocal performance.

Philosophy Courses:

The following courses may be used to fulfill Area 5:

Humanities of the General Education Core Curriculum (page 7).

PHIL 120, Introduction to Philosophy, 3 cr, 3 cl hrs

An exploration of major issues and approaches in the history and practice of philosophy, including questions of value, knowledge, reality, and problems that arise in social and political philosophy. A fundamental aim of the course is to improve skills in critical thinking, problem-solving, and evaluating.

PHIL 231, Western Philosophy, 3 cr, 3 cl hrs

Introduction to Western philosophical methods, metaphysics, epistemology, ethics, and major philosophers in comparison to one major Asian philosophy text such as the Tao Te Ching. [NMCCNS PHIL 1113: General Education Area V]

PHIL 323, American Nature Writing, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

A survey of American nature Writers, such as Lewis and Clark, Thoreau, Edward Abbey, and Leslie Marmon Silko, with literary and philosophical analysis of their observational, documentary, rhetorical, inter-disciplinary, and self-reflective strategies to develop students' own skills in these areas and to produce their own nature writing. (Same as ENGL 323)

PHIL 300, Philosophy of Science, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

An introduction to the philosophical bases and problems of the formal and empirical sciences. Includes the nature of scientific methods, problems and paradoxes of induction, logic of explanation, concepts of causality, determinism and probability, measurement theory, and special philosophical issues in physical, biological, and behavioral sciences.

PHIL 315, Philosophy of Digital Communication, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

A philosophical and historical overview of the shift to digital modes of communication; explores the impact of this digital shift on culture, identity, communication, education, art, medicine, ethics, community, and the production of knowledge. (Same as TC 315.)

PHIL 321, Professional Ethics, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Ethical theories and their applications in business, research, and engineering.

PHIL 342, Philosophy of Bioethics, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Exploration of ethical issues embedded in medicine and related activities; focuses on broad areas including: the physician/patient relationship, the media's influence on medicine, the role of the pharmaceutical industry, gene therapy, cloning and stem cell research, organ transplantation, human and animal research, reproductive technologies, and the global allocation of resources.

PHIL 351, World Religions, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Survey of the theologies of Christianity, Judaism, Islam, Hinduism, Buddhism, and other religions. [NMCCNS PHIL 1113: General Education Area V]

PHIL 352, Asian Philosophy, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Survey of the philosophical traditions of China (Confucianism and Taoism), India (Hinduism and Islam), and Japan (Buddhism).

PHIL 421, Periods or Figures in Philosophy, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Study of a single philosopher's work or a philosophical school.

PHIL 440, Philosophical Novels, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 and one PHIL course

Exploration of the use and articulation of philosophy in novels. (Same as ENGL 440)

PHIL 451, American Philosophy, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Survey of American philosophy, including pragmatism from its roots in American Romantic writers such as Emerson to contemporary figures such as Richard Rorty and Stanley Fish, nature philosophers such as Thoreau and Ed Abbey, feminist philosophy, and Native-American philosophy.

PHIL 521, Professional Ethics, 3 cr, 3 cl hrs

Introduce students to the concepts, theory, and practice of ethics and effective written and oral communications. Study cases and apply classical moral theory to decisions encountered in professional careers.

Political Science Courses:

The following courses may be used to fulfill Area 4: Social Sciences of the General Education Core Curriculum (page 7).

PS 151, Introduction to Political Science, 3 cr, 3 cl hrs

An introduction to political ideas, events and institutions. Explores the relationships between politics and society; examines the interdependence of citizenship and community life; investigates the complex interaction between values, issues and political behavior.

PS 171, American Government, 3 cr, 3 cl hrs

An examination of American democracy as a creative, evolving, and fluid process; how citizens and political institutions interact to create power, establish rights, and pursue interests. [NMCCNS GOVT 1113: General Education Area IV]

PS 361, Issues in International Relations, 3 cr, 3 cl hrs

Considers current international issues in light of the transforming structure of world politics; examines the changing status of America as a world power; and investigates the roles of culture, economic power, and technology in the process of global change.

PS 370, Public Policymaking, 3 cr, 3 cl hrs

An analytical examination of the policymaking process within the American political system, with special attention to who is involved in the process, how decisions are made, and what the consequences are of alternative policy choices.

Social Science Courses:

The following courses may be used to fulfill Area 4: Social Sciences of the General Education Core Curriculum (page 7).

SS 120, Social Thought, 3 cr, 3 cl hrs

From Machiavelli and Marx to Steinem and Foucault, this course explores some of the major historical and contemporary theoretical works and authors in selected social sciences. The focus is on the cultural framework in which these thoughts emerged and the impact they had on society. (Same as ANTH 120 and WGS 120)

SS 301, Interdisciplinary Problem Solving, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

An introduction to the Theory of Inventive Problem Solving (TRIZ), including techniques for problem definition, functional modeling, and concept generation. Emphasis on qualitative, interdisciplinary approaches to technical problems.

SS 501, Creative Problem Solving, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing or consent of instructor

Techniques for defining problems and generating solution concepts, using Theory of Inventive Problem Solving (TRIZ) methods and incorporating additional tools that provide clarity and flexibility when approaching challenges creatively. Emphasis on qualitative, interdisciplinary approaches to technical problems. Application of these methods to graduate students' own-and peers'-design and/or experimental problems.

Spanish Courses:

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

SPAN 113, Elementary Spanish I, 3 cr, 3 cl hrs

Elements of Spanish, with emphasis on the spoken language. Grammar and writing are introduced in connection with the subjects of oral practice. [NMCCNS SPAN 1113: General Education Area V]

SPAN 113N, Spanish for Native Speakers, 3 cr, 3 cl hrs

Elements of Spanish, with emphasis on the spoken and written language. Grammar and writing are introduced in connection with the subjects of oral practice.

SPAN 114, Elementary Spanish II, 3 cr, 3 cl hrs

Prerequisite: SPAN 113 or equivalent

Continuation of SPAN 113. [NMCCNS SPAN 1123: General Education Area V]

SPAN 215, Intermediate Spanish I, 3 cr, 3 cl hrs

Prerequisite: SPAN 114 or equivalent

Expansion of vocabulary through conversation. Stress is placed on the correction of vocabulary and speech for native speakers. Extensive readings from literary models provide materials for emphasis on the principles of composition. Review of grammar.

SPAN 216, Intermediate Spanish II, 3 cr, 3 cl hrs

Prerequisite: SPAN 215 or equivalent

Continuation of SPAN 215; readings in Spanish literature.

SPAN 352, Contemporary Latin American Novel, 3 cr, 3 cl hrs

Prerequisite: SPAN 215 or equivalent

Survey of the 20th century Latin American regional novel. How contemporary writers have portrayed the Latin American continent: social-realism, surrealism, the boom, neo-baroque, magical realism, mestizaje, social-protest, negrismo, etc. Focus on reading classical works such as Arguedas, Asturias, Castellanos, Fuentes, Roa Bastos, Rulfo. All readings and reports to be in Spanish. (Same as ENGL 352)

SPAN 355, Latin American Fiction & the Arts, 3 cr, 3 cl hrs

A historical journey of a multi-cultural continent. Politics, economic disparity, military dictatorship, oppression and revolutionary resistance are studied through the lens of arts and literature. The most varied styles—social-realism, surrealism, fantasy, magical-realism, etc.—complement factual history to offer an accurate picture of a cruel social reality. (Same as ENGL 355)

SPAN 357, Latin American Literature, 3 cr, 3 cl hrs

A review of Latin American literary production with examples of its cultural and artistic diversity. The class examines the most important writers from Mexico, the Caribbean, Central America, the Andean region and the Southern cone, and relates their poetic legacy to the social sciences and philosophy. (Same as ENGL 357)

SPAN 370, Nahuatl Mythology & Anthropology, 3 cr, 3 cl hr

A study of Native language, literature, and mythology of Central America. The class explores a specific native literature in its own language and discusses an “American” worldview. Topics include the concept of a fragmented self and of multiple souls, of political community and redistribution, a quintesimal (5) and vigesimal (20) system of counting, sexuality, and the foundation of a Native philosophy. (Same as ANTH 370)

SPAN 385, Latin American Cultural History, 3 cr, 3 cl hrs

Prerequisite: SPAN 215 or equivalent

Overview of the cultural history of the Iberian world on both sides of the Atlantic from the earliest cultural expression to the current Hispanic presence in the United States. Multicultural creations of Hispanic societies. Cultural productions, i.e., fiestas, toreo, music, painting, literature, graffiti—in their political, economic, and historical background. All readings and reports to be in Spanish. (Same as HIST 385)

SPAN 520, Advanced Spanish Reading & Comprehension, 1 cr, 1 cl hr

Creative writing in Spanish. The class explores the poetic and musical legacy of the Spanish speaking countries, and writes poems, short stories, or a small literary piece in Spanish.

Technical Communication Courses:

TC 100, Community Service, 1 cr, 1 cl hr

Proposing and then reporting in writing on a semester-long community service activity with any nonprofit organization. To be graded S/U. May be repeated for credit.

TC 101, Orientation to Technical Communication, 1 cr, 1 cl hr

Guest speakers introduce students to the myriad activities and career paths of technical communicators.

TC 151, Visual Communication, 3 cr, 3 cl hrs

Students are introduced to the significance of visual symbols in human communication. They learn fundamental graphic and document design principles, develop a vocabulary for analyzing the rhetoric, ethics, and politics of images, and apply this knowledge to the production of effective technical visuals.

TC 202, Elements of Editing, 3 cr, 3 cl hrs

Prerequisite: ENGL 112

Corequisite: TC 151

Grammar review. Description of types and levels of editing. Responsibilities of editors. Use of editing and proofreading symbols, usage guides, style guides, and style sheets. Production aspects of editing. Practice in online and hardcopy editing of short manuscripts.

TC 211, Media Studies, 3 cr, 3 cl hrs

Prerequisites: ENGL 112

Survey of media of mass communication, including print, television, film, and internet. Emphasis on social impact of media and on developing tools to examine media messages. Students will form research groups to present on and analyze selected media events.

TC 305, Science Writing, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 and at least junior standing or consent of instructor

This course provides an overview of science writing genres designed to reach multiple audiences (e.g., specialists, policymakers, students, the public, etc.). Course topics include, but are not limited to, the rhetorical history of science communication, popular science writing and science journalism, public information for research groups and facilities (e.g., press releases, websites, science blogs), and scholarly writing (e.g., journal articles, and grant proposals). This course is ideal for TC students interested in working for one of New Mexico's many national labs and research facilities and for students in the sciences interested in improving their scientific communication skills. Shares lecture with TC 505, with additional expectations for graduate credit.

TC 315, Philosophy of Digital Communication, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

A philosophical and historical overview of the shift to digital modes of communication; explores the impact of this digital shift on culture, identity, communication, education, art, medicine, ethics, community, and the production of knowledge. (Same as PHIL 315.)

TC 316, International Professional Communication, 3 cr, 3 cl hrs

Prerequisite: ENGL 112 or consent of instructor

Producing efficient and effective information for audiences situation in different geographic locations is a major concern of companies and organizations, both large and small. This course develops the knowledge and skills needed to analyze and solve the problems posed by a world that is increasingly diverse, interconnected, and driven by knowledge, technology and the capacity to learn and adapt to new and ever changing contexts and situations. During the course, students will produce artifacts that demonstrate development and accomplishments as an international professional communicator. Shares lecture with TC 512, with additional expectations for graduate credit.

TC 321, Internship, 3 cr

Prerequisites: TC 202 and 211; ENGL 341; and consent of TC faculty

Work during a school term or the summer in a technical communication or media field, such as writing, gathering data, or production work, for an on- or off-campus publications agency. To receive credit, students must have their internships approved in advance by the TC faculty. Students produce a report about their internship program.

TC 351, Web Design, 3 cr, 3 cl hrs

Prerequisites: TC 151

This course introduces students to the fundamentals of web design, including principles of usability, aesthetics, and interactivity. Students will learn and apply current web design theories and relevant technology tools to practical course projects.

TC 361, Advanced Visual Communication: Data Visualization, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 or consent of instructor

Knowing how to communicate information graphically and in such a way as to intuitively engage its audiences is a fundamental skill to have in a world permeated by data. This course develops the knowledge and skills needed to evaluate, plan and produce aesthetic, ethical, and functional data displays—graphs, charts, technical illustrations, maps, interactive displays, and others—for people engaged in science, technology, business, government, and academia, as well as for semi-specialized and lay audiences. Shares lecture with TC 561, with additional expectations for graduate credit.

TC 371, Publications Management, 3 cr, 3 cl hrs

Prerequisites: TC 202 and 211 or consent of instructor

Theory and practice of meeting managerial responsibilities. Topics include communication in organizations, management and supervision, project management, technology and professional communication, legal and ethical issues, and contract employment. Includes a collaborative research project using ethnographic methods.

TC 381, Studying Organizational Cultures, 3 cr, 3 cl hrs

Prerequisites: TC 202 and 211 or consent of instructor

Learning the practice and process of participant observations within the cultures of organizations. Exploring the differences within cultures and writing those observations as narratives.

TC 402, Comprehensive Technical Editing, 3 cr, 3 cl hrs

Prerequisites: TC 202 and ENGL 341

Working with full-length drafts, the course applies theory to problems in evaluating, revising, and designing documents, working with authors in different organizational settings, and writing and designing for international audiences. Course includes a research project and presentation.

TC 411, Persuasive Communication, 3 cr, 3 cl hrs

Prerequisites: TC 202 and 211, or consent of instructor

Theory and practice of producing proposals, sales literature, application letters, résumés, and other documents and media that promote the interest of individuals or organizations in industry and government. Topics in psychology, rhetoric, and advertising may be considered. Students gain practical experience in design, writing, and illustrating promotional texts, particularly technical proposals.

TC 420, Senior Seminar, 3 cr, 3 cl hrs

Prerequisites: TC 211 and senior standing in the Technical Communication program

Readings in professional journals and discussion of current issues in technical and professional communication. Taught as a seminar with students presenting papers. Research leading to proposal for TC 422, Senior Thesis.

TC 421, Professional Writing Workshop, 3 cr, 3 cl hrs

Prerequisites: TC 202 and 211, or consent of instructor

Emphasis on the development and writing processes of professional communication documents, which might include computer/software documentation, websites, videos, policy and procedural manuals. Students gain practical experience working on an in-depth documentation project with clients and developing materials for users.

TC 422, Senior Thesis, 3 cr, 3 cl hrs

Prerequisite: TC 420

Initiation, production, and presentation (oral and written) of an original research project in technical communication.

TC 461, Digital Media Design, 3 cr, 3 cl hrs

Prerequisites: TC 351 or consent of TC faculty

This course builds on the skills students learn in Web Design, providing the necessary tools and experience to build large-scale complex websites and applications. Through the course text, lectures, hands-on projects, and self-paced tutorials, students will explore and learn how to appropriately select from the many technological options available for designing large-scale digital projects.

TC 491, Directed Studies, 1–3 cr, as arranged

Prerequisites: TC 202 and 211, or consent of instructor

TC 505, Science Writing, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing

This course provides an overview of science writing genres designed to reach multiple audiences (e.g., specialists, policymakers, students, the public) and is useful both to students pursuing a career as a professional science or technical writer and to students in the sciences hoping to improve their communication skills. Course topics include, but are not limited to, popular science writing (e.g., writing for mainstream magazines and newspapers), public information (e.g., press releases, websites, science blogs, informational videos), and academic/research writing (e.g., journal articles, abstracts, and grant proposals). This course will also include a community service project providing students with an opportunity to generate real-world documents for a research facility at New Mexico Tech. Shares lecture with TC 305, with additional expectations for graduate credit.

TC 511, Persuasive Communication, 3 cr, 3 cl hrs

Prerequisites: Consent of instructor

Instruction in theories and practices of effective persuasive communication. Course content will include extensive audience analysis and planning, drafting, and revising persuasive documents, with a heavy emphasis on funding and research proposals, for targeted audiences.

TC 512, International Professional Communication, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing

Producing efficient and effective information for audiences situated in different geographic locations is a major concern of companies and organizations, both large and small. This course develops the knowledge and skills needed to analyze and solve the problems posed by a world that is increasingly diverse, interconnected, and driven by knowledge, technology, and the capacity to learn and adapt to new and ever changing contexts and situations. Students will compile a professional portfolio demonstrating development and accomplishments as an international professional communicator. Shares lecture with TC 316, with additional expectations for graduate credit.

TC 521, Professional Writing Workshop, 3 cr, 3 cl hrs

Emphasis on the development and writing processes of professional communication documents, which might include computer/software documentation, websites, videos, policy and procedural manuals. Students gain practical experience working on an in-depth documentation project with clients and developing materials for users.

TC 561, Data Visualization, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing or Consent of Instructor

Knowing how to communicate information graphically and in such a way as to intuitively engage its audiences is a fundamental skill to have in a world permeated by data. This course develops the knowledge and skills needed to evaluate, plan and produce aesthetic, ethical, and functional data displays—graphs, charts, technical illustrations, maps, interactive displays, and others—for people engaged in science, technology, business, government, and academia, as well as for semi-specialized and lay audiences. Shares lecture with TC 361, with additional expectations for graduate credit.

TC 589, Special Topics, 3 cr, 3 cl hrs**Theater Courses:**

The following courses may be used to fulfill Area 5: Humanities of the General Education Core Curriculum (page 7).

THEA 314, Introduction to Theater, 3 cr, 3 cl hrs

Theory and practice of analysis of the play as literature, applying basic modes of literary criticism and vocabulary of literary analysis. Coursework includes organizing and leading a discussion on such subjects as literary analysis, directing, scene or costume design, or playwriting. Practical application includes producing a readers' theater performance.

THEA 514, Introduction to Theater, 3 cr, 3 cl hrs

Theory and practice of analysis of the play as literature, applying basic modes of literary criticism and vocabulary of literary analysis. Coursework includes organizing and leading a discussion on such subjects as literary analysis, directing, scene or costume design, or playwriting. Practical application includes producing a readers' theater performance.

Women's and Gender Studies Courses:

The following courses may be used to fulfill Area 4: Social Sciences of the General Education Core Curriculum (page 7).

WGS 101, Introduction to Gender Studies, 3 cr, 3 cl hrs

This chronologically organized course follows the changes in defining women and men as gendered beings in the U.S. We explore such cultural areas as the economy, politics, sexualities, medicine, religions, and more, tracing how ideas of femininity and masculinity are created and enforced in various areas of American culture.

WGS 120, Social Thought, 3 cr, 3 cl hrs

From Machiavelli and Marx to Steinem and Foucault, this course explores some of the major historical and contemporary theoretical works and authors in selected social sciences. The focus is on the cultural framework in which these thoughts emerged and the impact they had on society. (Same as ANTH 120 and SS 120)

WGS 301, Introduction to Women's Studies, 3 cr, 3 cl hrs

This thematically organized course introduces issues important to women and men as gendered beings. Explorations of such cultural areas as the economy, politics, sexualities, medicine, religions, and more, both in their American context as well as in comparison to other cultures.

WGS 320, Anthropology of Sex and Gender, 3 cr, 3 cl hrs

A survey of the varieties of sex and gender definitions and roles in historical and contemporary human cultures. The study of sex assignment, gender definitions and roles in their association to stratified or equitable access to economic, political, and ideological resources and monopolies. Exploration of the parallels and differences between gender, race, and class. Topics include: gendered division of labor, female and male socialization, violence against women as male entertainment and female punishment, gender universals and generalities. (Same as ANTH 320.)

WGS 381, Qualitative Methods, 3 cr, 3 cl hrs

An introduction to the primary methods used in long-term qualitative data gathering, such as participant observation and deep ethnography, and in short-term applied data collection, such as focus groups and life histories. A major focus is research conducted with organizations and their culture. Students will design and execute their own research projects. (Same as ANTH 381 and TC 381)

Graduate Courses Offered:

The following courses are offered for graduate credit:

COMM 560, Professional Public Speaking, 3 cr, 3 cl hrs

Prerequisites: Consent of instructor

Theory and practice of ethical and professional speech communication. Research, writing and presenting professional presentations. Designing and using effective visuals, including posters and electronic presentation aids. Conducting group presentations and discussions about ethical and cross-curriculum issues in historical, cultural and workplace context. Design, schedule and present a formal research colloquium.

COMM 570, Communication in Engineering, 3 cr, 3 cl hrs

Prerequisites: Graduate Enrollment in Engineering

Advanced communication/writing courses linked to engineering disciplines, focusing on graduate and professional genres (e.g., conference abstracts, journal articles, and conference presentations). Emphasis on communicating technical information to a variety of audiences.

COMM 575, Communication in the Sciences 3 cr, 3 cl hrs

Prerequisites: Graduate Enrollment in Sciences

Advanced communication/writing courses linked to science disciplines, focusing on graduate and professional genres (e.g., conference abstracts, journal articles, and conference presentations). Emphasis on communicating technical information to a variety of audiences.

ENGL 501, Graduate Writing Seminar, 3 cr, 3 cl hrs

Prerequisite: Proficiency in written and spoken English, Graduate standing or consent of instructor

Intensive practice in academic writing for graduate students. Focuses on writing and revision. Reviews the history and development of science writing and surveys the professional environments in which scientists are expected to publish. Students should come with a draft of a substantial piece of work—such as an article, chapter, or grant proposal.

ENGL 511, Graduate Creative Writing, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Professional-level writing in fiction, poetry, creative non-fiction or plays. Focuses on the genre of the student's choice. Students write often, revise frequently, learn and apply methods of Creative Writing instruction.

ENGL 524, Ecotopia: The Intersection of Science and Literature, 3 cr, 3 cl hrs

Prerequisite: Graduate Standing or consent of instructor

Utopian Literature, whether Paradise myths or novels set on an idyllic island or in the future, chronicles human aspirations for a better society. Ecotopia—a neologism coined in 1968—combines utopian desires for better relationships between humans with more recent desires and need for a better relationship with the environment. The course provides a review of utopian literature throughout history and focuses on contemporary science fiction novels and developments in architecture, technology, science, and alternative social structures. Shares lecture with ENGL 324, with additional expectations for graduate credit.

PHIL 521, Professional Ethics, 3 cr, 3 cl hrs

Introduce students to the concepts, theory, and practice of ethics and effective written and oral communications. Study cases and apply classical moral theory to decisions encountered in professional careers.

SS 501, Creative Problem Solving, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing or consent of instructor

Techniques for defining problems and generating solution concepts, using Theory of Inventive Problem Solving (TRIZ) methods and incorporating additional tools that provide clarity and flexibility when approaching challenges creatively. Emphasis on qualitative, interdisciplinary approaches to technical problems. Application of these methods to graduate students' own-and peers'-design and/or experimental problems.

SPAN 520, Advanced Spanish Reading & Comprehension, 1 cr, 1 cl hr

Creative writing in Spanish. The class explores the poetic and musical legacy of the Spanish speaking countries, and writes poems, short stories, or a small literary piece in Spanish.

TC 505, Science Writing, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing

This course provides an overview of science writing genres designed to reach multiple audiences (e.g., specialists, policymakers, students, the public) and is useful both to students pursuing a career as a professional science or technical writer and to students in the sciences hoping to improve their communication skills. Course topics include, but are not limited to, popular science writing (e.g., writing for mainstream magazines and newspapers), public information (e.g., press releases, websites, science blogs, informational videos), and academic/research writing (e.g., journal articles, abstracts, and grant proposals). This course will also include a community service project providing students with an opportunity to generate real-world documents for a research facility at New Mexico Tech. Shares lecture with TC 305, with additional expectations for graduate credit.

TC 511, Persuasive Communication, 3 cr, 3 cl hrs

Prerequisites: Consent of instructor

Instruction in theories and practices of effective persuasive communication. Course content will include extensive audience analysis and planning, drafting, and revising persuasive documents, with a heavy emphasis on funding and research proposals, for targeted audiences.

TC 512, International Professional Communication, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing

Producing efficient and effective information for audiences situated in different geographic locations is a major concern of companies and organizations, both large and small. This course develops the knowledge and skills needed to analyze and solve the problems posed by a world that is increasingly diverse, interconnected, and driven by knowledge, technology, and the capacity to learn and adapt to new and ever changing contexts and situations. Students will compile a professional portfolio demonstrating development and accomplishments as an international professional communicator. Shares lecture with TC 316, with additional expectations for graduate credit.

TC 521, Professional Writing Workshop, 3 cr, 3 cl hrs

Emphasis on the development and writing processes of professional communication documents, which might include computer/software documentation, websites, videos, policy and procedural manuals. Students gain practical experience working on an in-depth documentation project with clients and developing materials for users.

TC 561, Data Visualization, 3 cr, 3 cl hrs

Prerequisites: Graduate Standing or Consent of Instructor

Knowing how to communicate information graphically and in such a way as to intuitively engage its audiences is a fundamental skill to have in a world permeated by data. This course develops the knowledge and skills needed to evaluate, plan and produce aesthetic, ethical, and functional data displays—graphs, charts, technical illustrations, maps, interactive displays, and others—for people engaged in science, technology, business, government, and academia, as well as for semi-specialized and lay audiences. Shares lecture with TC 361, with additional expectations for graduate credit.

TC 589, Special Topics, 3 cr, 3 cl hrs

Faculty Research Interests

- Dezember—Poetry, the Visual Arts and Poetry, American Literature
- Dotson—Science and technology studies
- Durão—Visual Communication with an emphasis on Data Visualization, Science and Technology Studies, International professional communication
- D. Dunston—Conducting, Music and Science, Creativity and Innovation
- S. Dunston—American Literature, Philosophy, Kramer-Simpson— Feedback, Transitioning from college to the workforce, Students developing research interests
- Lara-Martínez—Latin American Cultural History, Psychoanalysis
- Newmark – American and Multiethnic American Literature, Writing Across the Curriculum, Composition/Rhetoric.
- Prusin—Russia, Eastern Europe, Nationalism, Genocide
- Simpson—ESL Writing, Graduate Student Writing, Technical and Scientific Communication

Earth and Environmental Science

The Department of Earth and Environmental Science administers four closely related disciplines in the Earth sciences—geology, geophysics, geochemistry, and hydrology—as well as the various options leading to a Bachelor of Science degree in Environmental Science. By its very nature, Environmental Science is an interdisciplinary program, incorporating expertise from biology, chemistry, Earth science, physics, and environmental engineering.

Earth Science

Professors Bilek, Boston (Chair of the Department), Condie, Hendrickx, Kyle, Mozley, Person, Phillips, Wilson
Associate Professors Axen, Harrison, McIntosh, Spinelli
Assistant Professors Cadol, Grapenthin, Maher, Van Wijk
Research Professors Murray, Reusch, Ulmer-Scholle
Emeritus Professors Budding, Campbell, Gross, D. Johnson, Lattman, Sanford, Schlue
Adjunct Faculty Bauer, Broadhead, Buckley, Cather, Chamberlin, Chapin, Connell, Creech-Eakman, Dunbar, Hawley, Heizler, J. Johnson, Kelley, Kieft, Land, Love, McCord, McLemore, Pullin, Reiter, Rowe, Scholle, Stephens, Tidwell, Timmons, Vivoni

Degrees Offered: *B.S. in Earth Science with options in Geology, Geophysics, and Hydrology and B.S. in Earth Science; M.S. in Geochemistry, Geology, Geophysics (Solid Earth), and Hydrology; Ph.D. in Earth and Environmental Science with Dissertation in Geochemistry, Geology, Geophysics, or Hydrology*

Undergraduate degrees in Earth science require a broad-based background in mathematics, chemistry, and physics, as well as basic training in the Earth sciences. The curriculum emphasizes fundamentals and thus provides the background for entry into a number of Earth science professions or graduate schools.

The graduate program provides specialized training and research opportunities in theoretical or applied aspects of Earth science. Areas of particular expertise in the department include: ore genesis, origins of magmas, volcanology, tectonic history of the continents, geothermal and hydrocarbon exploration, recharge, flow, and water quality in groundwater basins and at hazardous waste sites, modern and ancient depositional processes and environments; landscape and soil evolution, atmospheric and land surface controls on regional energy and water budgets, earthquake seismology, seismic imaging, geodesy, faults and fluid flow, marine geophysics; radiometric dating, geobiology, and cave and karst studies. Staff members of the on-campus New Mexico Bureau of Geology and Mineral Resources participate in the graduate program by offering courses and supervising research work for theses and dissertations.

Earth science is a highly interdisciplinary field with many critical environmental, science, and resource connections to society. Graduates commonly enter professional careers in water resources, in the science, monitoring and management of geologic hazards and water quality, and in the exploration for and stewardship of energy and other natural resources.

Undergraduate Program

Bachelor of Science in Earth Science with or without options

Minimum credit hours required—130

Courses taken to fulfill mathematics and basic science requirements of the General Degree Requirements, and courses in Earth Science, taken to fulfill departmental requirements must be taken for a letter grade.

All degree options in the Bachelor of Science in Earth Science program share the following common core curriculum. Students may therefore immediately begin coursework for the major before choosing a specific option track.

Earth Science Core Curriculum

ERTH 200 (4), ERTH 201 (4), ERTH 202 (4), ERTH 203 (3), ERTH 204 (4), ERTH 205 (1), ERTH 390 (3), ERTH 325 (3), ERTH 340 (3)

Bachelor of Science in Earth Science with Geology Option

Minimum credit hours required—130

In addition to the General Education Core Curriculum Requirements (page 7), the following courses are required:

- A 100-level ERTH course and associated lab (4)
- Earth Science core [ERTH 200 (4), ERTH 201 (4), ERTH 202 (4), ERTH 203 (3), ERTH 204 (4), ERTH 205 (1), ERTH 325 (3), ERTH 340 (3), ERTH 390 (3)]
- ERTH 380 (4), ERTH 385 (3), ERTH 453 (4), ERTH 468 (3), either ERTH 483 (2), ERTH 484 (2), and ERTH 485 (2) or ERTH 480 (6)
- Earth science electives, minimum 9 credit hours in courses numbered 300 and above
- MATH 283 or 382 (3)
- Total of 3 credit hours 200-level or above from chemistry, mathematics, or physics
- Technical electives, minimum 12 credit hours from courses numbered 300 or above from the following fields: mathematics, biology, computer science, physics, chemistry, and engineering.
- Electives to complete 130 credit hours

Bachelor of Science in Earth Science with Geophysics Option

Minimum credit hours required—130

In addition to the General Education Core Curriculum Requirements (page 7), the following courses are required:

- A 100-level EARTH course and associated lab (4)
- Earth Science core [ERTH 200 (4), EARTH 201 (4), EARTH 202 (4), EARTH 203 (3), EARTH 204 (4), EARTH 205 (1), EARTH 325 (3), EARTH 340 (3), EARTH 390 (3)]
- EARTH 380 (4) or EARTH 385 (3), EARTH 448 (3), EARTH 468 (3)
- EARTH 483 (2) and EARTH 484 (2), or approved geophysics field experience (4)
- One of the following: PETR 370 (3), EARTH 434 (3), EARTH 445 (3), EARTH 453 (3), any GEOP(3)
- MATH 231 (4), MATH 254 (3), MATH 332 (3), MATH 335 (3), MATH 283 or 382 (3)
- PHYS 242 (4), PHYS 333 (3)
- Technical electives, minimum 3 credit hours from courses numbered 300 or above from the following fields: mathematics, biology, computer science, physics, chemistry, and engineering.
- Earth science elective in courses numbered 300 and above (3)
- Electives to reach 130 credit hours

Bachelor of Science in Earth Science with Hydrology Option

Minimum credit hours required: 130

In addition to the General Education Core Curriculum Requirements, (page 7) the following courses are required:

- A 100-level EARTH course and associated lab (4)
- Earth Science core [ERTH 200 (4), EARTH 201 (4), EARTH 202 (4), EARTH 203 (3), EARTH 204 (4), EARTH 205 (1), EARTH 325 (3), EARTH 340 (3), EARTH 390 (3)]
- EARTH 384 (1), EARTH 440 (3) and 440L (1), EARTH 441 (1), EARTH 442 (1), EARTH 443 (1), EARTH 483 (2), EARTH 484 (2)
- Math 231 (4), Math 283 (3), Math 335 (3)
- Earth science electives, minimum 11 credit hours in courses numbered 300 and above
- CHEM 311 & 311L (4), ENVS 412 (3), CSE 113 & 113L (4)
- Electives to complete 130 credit hours

Bachelor of Science in Earth Science with Mineral Resources Option

Minimum credit hours required—130

In addition to the General Education Core Curriculum Requirements (page 7), the following courses are required:

- EARTH 101 with associated lab (4)
- Earth Science core [ERTH 200 (4), EARTH 201 (4), EARTH 202 (4), EARTH 203 (3), EARTH 204 (4), EARTH 205 (1), EARTH 325 (3), EARTH 340 (3), EARTH 390 (3)]
- EARTH 380 (4), EARTH 431 (3), EARTH 453 (4), EARTH 462 (3), EARTH 480 (6), EARTH 4xx (3) [Environmental Geochemistry of Mining Activities]
- ME 320 (2), ME 340 (3)
- Technical electives, minimum 3 credit hours from courses numbered 300 or above from the following fields: mathematics, biology, computer science, physics, chemistry, and engineering.
- Earth science and mineral engineering electives, 12 credit hours from the following classes: EARTH 360 (2), EARTH 407/GEOC 507 (3), EARTH 431/GEOC 531 (3), EARTH 465/GEOC 565 (3), ME 522 (3), ME523 (3), ME 551 (3)
- Electives to reach 130 credit hours

Bachelor of Science in Earth Science

Minimum credit hours required—130

In addition to the General Education Core Curriculum Requirements (page 7), the following courses are required:

- A 100-level EARTH course and associated lab (4)
- Earth Science core [ERTH 200 (4), EARTH 201 (4), EARTH 202 (4), EARTH 203 (3), EARTH 204 (4), EARTH 205 (1), EARTH 325 (3), EARTH 340 (3), EARTH 390 (3)]
- EARTH 384 (1), EARTH 483 (2), EARTH 484 (2)
- Earth science electives, minimum 24 credit hours in courses numbered 300 and above
- MATH 283 (3) or 382 (3)
- Total of 3 credit hours 200-level or above from chemistry, mathematics, or physics
- Technical electives, minimum 9 credit hours from courses numbered 300 or above from the following fields: mathematics, biology, computer science, physics, chemistry, and engineering.
- Electives to complete 130 credit hours

Minor in Earth Science

Minimum credit hours required — 18

The following courses are required:

- One 100-level EARTH class and associated lab (4 hrs)
- Two classes from the following list: EARTH 200, 201, 202, 203, or 204
- Additional 200-level or higher from EARTH, GEOL, GEOP, GEOC, or HYD, to reach 18 credits

Minor in Geobiology

Minimum credit hours required — 18

The following courses are required:

- EARTH 101 (3), EARTH 101L or 103L (1), EARTH 201 & 201L (4)
- BIOL 111 & 111L (4)
- Two classes from the following list: EARTH 450 (3), EARTH 390 (3), BIOL 341 (3), BIOL 344 (3), EARTH 449/BIOL 449 (3)

Minor in Geophysics

Minimum credit hours required — 19-20

The following courses are required:

- EARTH 101 (3), EARTH 101L or 103L (1), EARTH 412 (3)
- One class from the following list: EARTH 204 (4), EARTH 325 (3)
- Three classes from the following list: EARTH 445 (3), EARTH 448 (3), PHYS 242 (3), PHYS 333 (3)

Minor in Hydrology

Minimum credit hours required — 17-18

The following courses are required:

- EARTH 101 (3), EARTH 101L or 103L (1), EARTH 412 (3), EARTH 440 (3), EARTH 440L (1)
- One class from the following list: EARTH 340 (3), EARTH 441 & 442 & 443 (3), EARTH 407 (3)
- One class from the following list: MATH 335 (3), CHEM 422 (3)

Minor in Mineral Resources

Minimum credit hours required — 20

The following courses are required:

- EARTH 101 (3), EARTH 101L or 103L (1), EARTH 412 (3), EARTH 200 (4), EARTH 462/ME 462 (3)
- Two classes from the following list: EARTH 431(3), GEOL 551 (3), ME 220 (3), ME 360 (3)

Minor in Petroleum Geology

Minimum credit hours required — 17-18

The following courses are required:

- EARTH 101 (3), EARTH 101L or 103L (1), EARTH 203 (4), EARTH 447 (3), EARTH 460 (3)
- One class from the following list: EARTH 445(3), EARTH 453 (4), EARTH 461 (3)

Earth Science Courses:

ERTH 101, Earth Processes, 3 cr, 3 cl hrs

Offered fall semester

A study of the physical processes that operate on and within the Earth and determine its evolution through geologic time. Students are encouraged to enroll concurrently in EARTH 101L or EARTH 103L. [NMCCNS GEOL 1114: General Education Area III]

ERTH 101L, Earth Processes Laboratory, 1 cr, 3 lab hrs

Corequisite: EARTH 101

For students majoring in Earth sciences. Identification of rocks and minerals, maps and map reading, and measurement and interpretation of geologic features. Field trips. [NMCNNS GEOL 1114: General Education Area III]

ERTH 103L, Earth Processes Laboratory for Non-Majors, 1 cr, 3 lab hrs

Corequisite: EARTH 101

Laboratory to accompany EARTH 101 for students not majoring in the Earth sciences. Identification of rocks and minerals, maps and map reading, and measurement and interpretation of geologic features.

ERTH 120, Introductory Oceanography, 3 cr, 3 cl hrs

Offered spring semester, odd-numbered years

An introduction to the oceans, including aspects of physical, geological, and biological oceanography. Focus is on presentation of science in a social context. Topics include: origin and evolution of ocean basins and marine sediments; ocean currents, waves, tides, and sea level; beaches, shorelines, and coastal processes; marine life; climate; marine resources, pollution, and human impacts on the ocean.

ERTH 120L, Oceanography Laboratory, 1 cr, 3 lab hrs

Corequisite: EARTH 120

Hands-on laboratory exercises in oceanographic processes, including mapping of ocean basins and bathymetry, sediments and deposition, waves, salinity and thermohaline processes, tides, and marine ecosystems.

ERTH 130, Spaceship Earth, 3cr, 3 cl hrs

Offered fall semester, even-numbered years

Study of Earth as an immense system composed of a gigantic rocky mass, a planet-dominating ocean, an active atmosphere, and an abundance of life. Consideration of subsystems interacting across time and space. Discussion of possible mechanisms that may control this megasystem including controversial topics, e.g. co-evolution, homeostatic feedback mechanisms, and the Gaia Hypothesis.

ERTH 130L, Spaceship Earth Laboratory, 1cr, 3 lab hrs

Corequisite: EARTH 130

Laboratory and field demonstrations of principles of global biogeochemical cycles and the interaction of life with its planetary home.

ERTH 140 Water in the Rise and Fall of Civilizations, 3 cr, 3 cl hrs

Offered on demand

A survey of how water resources have nurtured the rise of civilizations and how changes in, or misuse of, these resources have led to their demise. The impact of hydrologic extremes such as floods and droughts on social sustainability will also be examined. Case studies from the ancient to the modern world will be considered in the context of the underlying hydrological processes and their environmental and social ramifications.

ERTH 140L, Water in the Rise and Fall of Civilizations Laboratory, 1 cr, 3 lab hrs

Corequisite: EARTH 140

Offered on demand

Laboratory and field exercises in hydrologic processes including flood forecasting, erosion, salinization, and groundwater overdraft.

ERTH 150, The Catastrophic Earth: An Introduction to Natural Hazards, 3 cr, 3 cl hrs

Offered spring semester, even-numbered years

A survey of natural hazards—such as earthquakes, volcanoes, slope failures, severe weather, asteroid impacts, and fire—and their societal implications. Scientific principles such as plate tectonics, volcanology, weather, space science, and statistics of hazard occurrences, as well as topical discussions of natural hazards in the news.

ERTH 150L, Catastrophic Earth Laboratory, 1 cr, 3 lab hrs

Corequisite: EARTH 150

Laboratory exercises dealing with natural hazards, including locating recent earthquakes using seismograms, combining maps of earthquake and volcanic hazards with statistical hazard information, estimating flood recurrence for rivers, and tracking hurricanes using meteorological data.

ERTH 200, Introduction to Mineralogy, 4 cr, 3 cls hrs, 3 lab hrs

Prerequisite: a 100-level EARTH course, EARTH 101L, CHEM 121, CHEM 121L

Offered spring semester.

An introduction to minerals, including identification in hand samples and thin sections, crystal structures, physical properties, chemical compositions, occurrences and uses. Lab will focus on mineral identification by physical and optical properties.

ERTH 201, Geobiology, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: a 100-level EARTH course

Corequisite: EARTH 101L

Offered spring semester, odd-numbered years

Consideration of life and its impact on the Earth System over the course of Earth history including its preserved geochemical and fossil remains, study of the observable geological effects of life processes and in turn the impact of geological, hydrological, and atmospheric effects on the origins and subsequent evolution of life. Field trips.

ERTH 202, Earth Surface Processes and Landforms, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: Any EARTH 100 level class

Corequisite: EARTH 101L

Offered fall semester, odd-numbered years

A study of the interactions between the atmosphere and the internal heat of the Earth which result in the development of landscapes observable at the Earth's surface today. Topics will include atmospheric circulation, climate, fluvial processes, and the record of paleoclimate contained in the landscape. Field trips.

ERTH 203, Earth's Crust: Materials, Processes, and Dynamics, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: a 100-level EARTH course and EARTH 101L

Offered spring semester

Overview of the evolution of the crust of the Earth, the major rock types and processes that form it, and the main methods used to study it. Topics include sedimentology, petrology, structural geology, geochronology, subsurface fluid flow, and petroleum geology. Field trips.

ERTH 204, Introduction to Whole Earth Structure and Composition, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: a 100-level EARTH course

Corequisite: EARTH 101L

Offered fall semester, even-numbered years

Introduction to geophysical and geochemical methods used to study the deep Earth. Formation, composition and internal structure of the Earth, plate tectonics, gravitational and magnetic fields, heat flow and thermal history, earthquakes, and interaction of Earth systems with emphasis on the crust, mantle and core. Introduction to mantle convection, geochemical reservoirs, and mantle plumes. Field trips.

ERTH 205, Earth Science Practicum, 1 cr, 3 lab hrs

Prerequisite: a 100-level EARTH course

Corequisite: EARTH 101L

Offered fall semester.

Instruction and practice in computational methods used to solve Earth science problems. Simple ways to describe physical processes mathematically, then approximate them numerically. Introduction to spreadsheets and graphics programs. Review of math and statistics.

ERTH 325, Near-Surface Geophysics, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: PHYS 121; a 100-level EARTH course and associated lab

Offered fall semester, even-numbered years.

Theory and practice of geophysical methods for exploring the shallow subsurface, with emphasis on electromagnetic methods including resistivity, EM conductivity, ground-penetrating radar, and magnetic field strength. Applications to environmental hazards, hydrogeological features, and/or archaeology are emphasized in a hands-on, field-oriented approach.

ERTH 340, Global Climate Change: Origins and Impacts, 3 cr, 3 cl hrs

Prerequisites: MATH 132, PHYS 122

Offered spring semester, even-numbered years

How is global warming affecting the occurrence of floods and droughts, and human development influencing their severity and extent? This class will provide an introduction to the global hydrologic cycle and the potential changes caused by global climate change in the presence of a growing human population. Examples of recent research pointing to an accelerated hydrologic cycle will be discussed, including remote sensing and numerical modeling studies. Implications for sustainable human development and ecosystems will be explored, especially for the semiarid Southwest.

ERTH 360, Earth Resources and Environmental Issues, 2 cr, 2 cl hrs, 3 lab hrs

Prerequisites: Any 200-level EARTH class with associated lab

Offered fall semester, on demand

Overview of the economics, geologic occurrence and extraction of earth resources. Coverage includes metallic, non-metallic, and energy resources, soils and groundwater, and the environmental impacts related to their use and extraction. Field trip.

ERTH 380, Igneous and Metamorphic Petrology, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EARTH 200, 203, CHEM 121, CHEM 122

Offered spring semesters, odd-numbered years

Origin, occurrence, identification and description of igneous and metamorphic rocks. Topics covered include fractional crystallization and melting processes, physical and chemical properties of magmas, granitic batholiths, metamorphic facies and their key mineral assemblages, metamorphic rock fabrics, and qualitative determination of P-T-t paths recorded by metamorphic rocks. Binary and ternary phase diagrams will be introduced and used. Examination and identification of igneous and metamorphic rocks and minerals and their salient textures in thin section and hand samples.

ERTH 384, Stratigraphy, 1 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 203

Corequisite: EARTH 201

Offered spring semester, even-numbered years

Survey of lithostratigraphic, biostratigraphic and chronostratigraphic principles. Topics include seismic and sequence stratigraphy and stratigraphic modeling. Weekend field trip required. Meets with EARTH 385 for the first third of the semester.

ERTH 385, Stratigraphy and Paleontology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 203

Corequisite: EARTH 201

Offered spring semester, even-numbered years

Continuation of paleontologic and stratigraphic principles; survey of geologically important invertebrate biota preserved as fossils; their modes of preservation, collection techniques, taxonomy, evolution, paleobiology and paleoecology; overview of the late Precambrian and Phanerozoic biotic and stratigraphic histories in the context of North American tectonics. Weekend field trips required.

ERTH 390, Principles of Geochemistry, 3 cr, 3 cl hrs

Prerequisites: CHEM 122 and EARTH 200

Offered fall semester, even-numbered years

Application of chemical principles to geologic processes. Topics include mineral and rock chemistry, aqueous geochemistry and geochronology.

ERTH 405, Introduction to Soils, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite or Corequisite: EARTH 202

Offered spring semester

Introduction to soil formation, pedogenic processes, and soil description and mapping techniques. Meets with GEOL 503.

ERTH 407, Hydrogeochemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 122

Pre- or Corequisite: EARTH 440

Offered fall semesters

The thermodynamics and aqueous chemistry of natural waters, with emphasis on groundwater. Chemical equilibrium concepts, surface chemistry, redox reactions, and biochemistry. The interaction of water with the atmosphere and geologic materials. Basic concepts applied to problems of groundwater quality evolution, water use, and groundwater contamination. Shares lecture with GEOC 507, HYD 507, and CHEM 531 with additional expectations for graduate credit. (Same as CHEM 431.)

ERTH 408, Cooperative Education

On-the-job training to supplement the academic program. Students alternate periods (usually six months long) of full-time semiprofessional employment in their chosen field with periods of full-time academic study.

ERTH 409, Soil Geomorphology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: EARTH 202 and 403; or consent of instructor
Offered on demand

Discussion of the use of soils to interpret the rate and timing of geomorphic processes and changing environmental parameters. Field trips.

ERTH 412, Introduction to Geographic Information Systems, 3 cr, 2 cl hrs, 3 lab hrs

Offered on Demand

An introduction to the concepts of geographic information systems (GIS). Theoretical background to GIS; introduction to the nature and analysis of spatial data. ArcView and/or ArcGIS. Shares lecture with GEOL 512, with additional expectations for graduate credit. Same as ENVS 412.

ERTH 424, Sedimentary Petrography, 3 cr, 4 lab hrs

Prerequisite: EARTH 200, 202, 203 or consent of instructor
Offered Spring Semesters, on demand

Petrographic analysis and interpretation of sedimentary rocks, with emphasis on siliciclastics. Topics include: grain identification and provenance, identification of diagenetic minerals and textures, and interpretation of porosity and permeability characteristics.

ERTH 425, Carbonate Sedimentology and Diagenesis, 3 cr, 3 cl hrs

Prerequisite: EARTH 200, 202 and 203 or consent of instructor
Offered on demand

This class covers the basics of carbonate sedimentation and diagenesis and looks at the evolution of carbonate sediments through geologic time (from Precambrian to recent). Included in the class are discussions of the impact of diagenesis on petroleum reservoir and aquifer potential. Shares lecture with GEOL 525 but is graded separately.

ERTH 427, Carbon Sequestration Science, 3 cr, 3 cl hrs

Prerequisite: Math 132, Chem 122, Phys 122, one 100-level EARTH course

Offered on demand

Overview of geological carbon sequestration. Topics include: Earth's changing climate, sources and sinks of greenhouse gases, carbon capture, reservoirs and caprocks, physical and aqueous chemistry of CO₂. Field trips.

ERTH 430, Active Tectonics, 3 cr hrs

Prerequisites: EARTH 202, 203

Offered on demand

Study of Quaternary faults, including basic field techniques, tectonic geomorphology from fault scarps to mountain fronts, patterns of faulting, structural analysis of faults in alluvium, relation of surface to subsurface structures, paleoseismology, and review of Quaternary dating methods.

ERTH 431, Exploration Geochemistry, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 380; EARTH 462 is recommended

Pre- or Corequisite: EARTH 412 or equivalent

Offered spring semester on demand

An introduction to the generation, evaluation, and interpretation of geochemical datasets used in mineral exploration. Overview of trace element behavior in geologic environments. Sampling methodology and media, analytical techniques, data quality evaluation, and report writing. Field trip. Shares lecture with GEOL 531, with additional expectations for graduate credit.

ERTH 432, Interdisciplinary Field Research, 3 cr, 8 lab hrs

Prerequisite: Consent of instructor

Offered fall semester on demand

Introduction to field-based research. Activities include proposal writing, data collection, interpretation, and preparation of a written report. Field work is an important part of the course, and hiking is required. The course is team-taught by several instructors.

ERTH 434, 434D, Introduction to Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS 122 or 132 or consent of instructor

Introduction to the theory and practical use of remotely sensed satellite images. Principles of radiation physics; sensor systems; data acquisition; image analysis; classification schemes. Remote sensing applications to atmospheric sciences, hydrology, mineral and oil exploration, natural hazards monitoring, and land and resources management. Become familiar with ERDAS Imagine remote sensing software. Laboratory exercises deal primarily with computer analysis of remotely-sensed images with some field exercises. Shares lecture/lab with GEOL/GEOP/HYD 534, with additional expectations for graduate credit.

ERTH 436, Advanced Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 434 or HYD 534 or GEOL 534

This class deals with quantitative remote sensing for determination of the components of the energy balance (net radiation, latent and sensible heat fluxes, soil heat flux) and soil moisture, hyperspectral and multispectral image processing, radar and microwave imagery. In addition, advanced applications for geology, geophysics and geochemistry will be discussed. Shares lecture/lab with GEOL/HYD 536, with additional expectations for graduate credit.

ERTH 437, Volcanology Field Trip, 1-6 cr

Offered on demand

Field trip to study volcanic rocks in a specific area or volcanological processes at an active volcano. A weekly seminar will precede a one-to two-week field trip. A paper is required. A student may register for the class more than once for a total of six credit hours. Shares lecture with GEOL 537, with additional expectations for graduate credit.

ERTH 440, 440D, Hydrological Theory and Field Methods, 3 cr, 3 cl hrs

Prerequisites: MATH 132, PHYS 132 122

Offered fall semester

Fundamentals of hydrological flow and transport will be presented. Precipitation, runoff processes, and flood generation. Capillarity, unsaturated flow, and infiltration. Laws of flow in porous media, hydraulic storage, and flow to wells.

ERTH440L, Hydrological Theory and Field Methods Laboratory, 1 cr, 3 lab hrs.

Prerequisites: MATH 132, PHYS 122 132; Co- or prerequisite: EARTH 440

Offered fall semester

Laboratory and field exercises that demonstrate and implement fundamental concepts of the hydrological cycle.

ERTH 441, 441D, Hydrogeology, 1 cr, 1 cl hr

Prerequisite: EARTH 440

Offered spring semester

Hydrogeologic controls on the occurrence, movement, and chemical and isotopic composition of groundwater. Hydrogeologic properties. Groundwater recharge and stream/aquifer interaction. Groundwater in different geological, climate, and physiographic regimes.

ERTH 442, 442D, Vadose Zone Processes, 1 cr, 1 cl hr

Prerequisite: EARTH 440

Offered spring semester

Physics of unsaturated flow in porous media, multi-phase flow, potentials and water retention, unsaturated hydraulic conductivity, transient flow problems.

ERTH 443, 443D, Atmospheric Dynamics and Rainfall and Evaporation Processes, 1 cr, 1 cl hr

Prerequisite: EARTH 440

Offered spring semester

Principles of atmospheric processes with an emphasis on rainfall generation and evaporation at the Earth's surface. Warm and cloud convection, orographic controls on precipitation, cyclogenesis and frontal storms. Particular attention paid to the measurement and assessment of rainfall and evaporation in space and time.

ERTH 444, Principles of Isotope Geochemistry, 3 cr, 3 cl hrs

Prerequisites: CHEM 122; EARTH 203

Offered spring semester

Principles of radiogenic isotope geochemistry and applications to geologic dating and to the petrogenesis of rock suites. Shares lecture with GEOC 544, with additional expectations for graduate credit.

ERTH 445, Petroleum Exploration Seismology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: PHYS 121 or equivalent; a 100-level EARTH course and associated lab; upper-class standing

Offered fall semester, odd-numbered years

An introductory course on seismic refraction and reflection imaging of the subsurface, with applications for petroleum, crustal and environmental problems. This course covers methods of data acquisition, processing, and interpretation. Topics include: survey geometries, data editing techniques, amplitude recovery, (bandpass) filtering, deconvolution, velocity analysis and migration, well log to seismic ties, contour maps, time-to-depth conversion. Designed for students with a range of Earth science and engineering backgrounds. Shares lecture with GEOL/GEOP 545 with additional expectations for graduate credit.

ERTH 446, Reflection Seismic Data Interpretation, 3 cr, 2 cl hrs, 2 lab hrs

Prerequisites: EARTH 445 or equivalent, upper-class standing, or consent of instructor

Offered on demand

An overview of the fundamentals of the geologic (both structural and stratigraphic) interpretation of 2D and 3D reflection seismic data. An introduction to seismic acquisition and processing and their effects on interpretation. Techniques covered include: well log to seismic ties, contour maps, fault plane maps, time-to-depth conversion, seismic sequence analysis, and workstation interpretation of 3D data. Designed for students with a range of earth science and engineering backgrounds.

ERTH 447, Depositional Systems and Basin Analysis, 3 cr, 3 cl hrs

Prerequisites: EARTH 202 and EARTH 203

Offered fall semester

Discussion of the spectrum of modern and ancient depositional environments and their relationships to tectonic settings. Shares lecture with GEOL 547, but is graded separately.

ERTH 448, General Geophysics, 3 cr, 3 cl hrs

Prerequisites: PHYS 122; a 100-level EARTH course and associated lab; upper-class standing

Offered fall, even-numbered years

An introduction to the general field of solid Earth geophysics. Subjects covered are the origin of the Earth; structure and internal properties of the Earth; gravity, magnetic, and temperature fields of the Earth; origin of the Earth's atmosphere, hydrosphere, and surface features.

ERTH 449 Astrobiology, 3 cr, 3 cl hrs

Prerequisites: CHEM 122, PHYSICS 122, plus one other science course and consent of instructor.

Offered spring semester, even-numbered years

An in-depth and interdisciplinary study of astrobiology, including interactions between living and non-living systems at multiple scales: stellar, planetary, meso, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principles of astrophysics, geosciences, planetary science, chemistry, and biology. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with GEOL 549, with additional expectations for graduate credit. (Same as BIOL 449/549)

ERTH 450, Cave and Karst Systems, 3 cr, 3 cl hrs

Prerequisites: CHEM 121 & 122; and either a 100-level EARTH course with associated lab, or BIOL 111

Offered fall semester, odd-numbered years

A system-based study of caves and karstic terrains over time including formation mechanisms (speleogenesis), hydrology, geochemistry, mineralogy, and geomicrobiology. Emphasis on caves as interactive microcosms cross-cutting many disciplines. Shares lecture with GEOL 550, with additional expectations for graduate credit.

ERTH 450L, Cave and Karst Lab, 1 cr, 3 lab hrs

Offered spring semester, even years

Corequisite: EARTH 450

Survey of techniques applicable to various aspects of speleology and karst studies. Project-based lab, developed for each student in consultation with instructor. Shares lab with GEOL, with additional expectations for graduate credit.

ERTH 453 Intermediate Structural Geology, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EARTH 203; PHYS 121; MATH 131

Offered fall semester, odd-numbered years.

Builds on basics of structural geology taught in EARTH 203. Elements of fault, fold, and rock mechanics; strain analysis and inference of stress in Earth's crust; construction of balanced, kinematically viable cross sections; brittle and ductile shear-sense indicators in faults and shear zones. Shares lecture and lab with GEOL 553 with additional expectations for graduate credit.

ERTH 456, Volcanology, 3 cr, 2-3 cl hrs, 1-3 lab hrs

Prerequisite: EARTH 380 or consent of instructor

Offered on demand

Detailed studies of volcanic process, pyroclastic rocks and mechanism of volcanic eruptions. Field trips to nearby volcanic regions. Shares lecture and field work with GEOL, with additional expectations for graduate credit.

ERTH 457, Reflection Seismic Data Processing, 3 cr, 2 cl hrs, 2 lab hrs

Prerequisites: EARTH 445 or equivalent, upper-class standing, or consent of instructor

Offered spring semester, odd numbered years

The computer application of digital signal processing to reflection seismic data from environmental, petroleum, and crustal surveys. Topics covered include: definition of survey geometries, data editing techniques, amplitude recovery, bandpass filtering, deconvolution, velocity analysis, F-K filtering, and migration.

ERTH 459, Geodynamics, 3 cr, 3 cl hrs

Prerequisites: EARTH 203 or 204

Offered spring semester, even-numbered years

How does the Earth deform? Theory of mantle convection, rheology of the mantle and lithosphere, lithosphere deformation, heat transport in the Earth, and melting. Emphasis is on current controversies in geodynamics, and the formulation of mathematical models that explain the physical observations. Shares lecture with GEOL/GEOP 559 with additional expectations for graduate credit.

ERTH 460, Subsurface and Petroleum Geology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 203

Offered spring semester

Principles of subsurface geology, geophysics, and basin analysis applied to petroleum systems. Topics include: composition, movement, and entrapment of petroleum; subsurface fluid pressure regimes (hydrostatic and dynamic); thermal evolution of sedimentary basins and petroleum source rock analysis; geodynamics of sedimentary and rock properties. Laboratory work includes measurements of porosity and permeability, structure contouring, pore pressure analysis of evolving sedimentary basins, bore hole correlation using geophysical well logs, reservoir volumetric calculations, construction of geologic cross sections; well hydraulics, and petroleum system modeling.

ERTH 461, Reservoir and Caprock Analysis 3 cr, 2 cl hrs,

Prerequisite: EARTH 202 and EARTH 203 or consent of instructor

Offered on demand

The class focuses on the role of sedimentary and structural heterogeneities in controlling porosity, permeability, and fluid flow in the subsurface. Topics include controls on conventional and unconventional reservoir quality and performance, evaluating caprock integrity, and the influence of faults and fracture networks on fluid flow. Applications to petroleum geology, petroleum engineering, carbon sequestration, and hydrology. There is a mandatory field trip associated with the class, which involves camping and moderately strenuous hiking on uneven ground. Shares lecture with GEOL 561, with additional expectations for graduate credit.

ERTH 462, Mineral Deposits, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 203

Offered spring semester, alternate years

Geologic and geochemical characteristics of metallic mineral deposits; theories of origin and classification.

ERTH 468, Evolution of the Earth, 3 cr, 3 cl hrs

Prerequisites: EARTH 201, 203, 204

Offered spring semester

Origin of the solar system and of the Earth; the evolution of continents, atmosphere, and oceans; comparative planetary evolution; tectonic regimes in geologic history.

ERTH 480, Field Methods in Earth Science, 6 cr

Prerequisites: EARTH 200, 203, 380 and 384 or 385. EARTH 202 and 453 recommended.

Offered summers (6 weeks); NMT students should register for this course in the spring semester.

Collection, processing, and interpretation of field data developed by geologic mapping in sedimentary, igneous, and metamorphic terrane. Presentation of geologic reports involving maps, cross sections, and sample data.

ERTH 483, Field Methods in Earth Science I, 2 cr

Prerequisites: EARTH 200, 203, 384 or 385

Offered Summers (2 weeks); NMT students should register for this course in the spring semester.

Collection, processing and interpretation of geological data from stratified rocks, collected by geologic mapping and other means. Presentation of geologic reports involving stratigraphic sections, maps, cross sections, and other data.

ERTH 484, Field Methods in Earth Science II, 2 cr

Prerequisites: EARTH 483; EARTH 202 or equivalent recommended

Offered summers (2 weeks); NMT students should register for this course in the spring semester.

Collection, processing and interpretation of geological data from landforms and unconsolidated regolith, collected by geologic mapping and other means. Presentation of geologic reports involving maps, cross sections, and other data.

ERTH 485, Field Methods in Earth Science III, 2 cr

Prerequisites: EARTH 380, 483; EARTH 453 recommended

Offered summers (2 weeks); NMT students should register for this course in the spring semester.

Collection, processing and interpretation of geological data from igneous, metamorphic and/or structurally complex rocks. Presentation of geologic reports involving maps, cross sections, and other data.

ERTH 491, 491D, Special Topics, hrs and crs to be arranged

Individual directed study in Earth Sciences.

ERTH 492, Senior Thesis, 3 cr

Prerequisite: 3.0 GPA in Earth science courses and consent of instructor

Individual research under the direction of a faculty member. Two semesters are usually necessary to complete the research project. Grading will be based on a written report which details the research goals, data collected, interpretation, and conclusions.

ERTH 493, Seminar, 1 cr, 1 cl hr

Offered fall and spring semesters

Seminar presentations by faculty, students, and outside speakers. Provides a broad overview of current Earth Science research and directions. Graded on S/U basis. Satisfactory performance consists of regular attendance at approved seminars. Credit may not be applied toward degree requirements. Shares lecture with GEOC 593, GEOL 593, GEOP 593, HYD 593, with additional expectations for graduate credit.

Geology

The Geology program offers an undergraduate degree in Earth Science with Geology option. See page 51.

Graduate Program

Master of Science in Geology

The master's candidate must demonstrate competence in mathematics, chemistry, and physics comparable to the requirements for the Bachelor of Science degree in Geology. The Master of Science degree in Geology may be earned under either of the following plans:

With Thesis:

The student's course of study must be approved by the advisory committee and must fulfill the general requirements for the master's degree with thesis and must include EARTH 480 or the equivalent, if not previously satisfied, two credits of GEOL 592, at least six credit hours of GEOL 591, and at least four credit hours of GEOL 593, unless the degree is completed in a shorter time. Credits earned in GEOL 592 and 593 may not be applied towards the 30 credits required for the M.S. degree.

Without Thesis:

The student's course of study must be approved by the advisory committee and must fulfill the general requirements for the master's degree without thesis and must include EARTH 480 or the equivalent, if not previously satisfied, two credits of GEOL 592, at least three credit hours of GEOL 590, and at least four credit hours of GEOL 593, unless the degree is completed in a shorter time. Credits earned in GEOL 592 and 593 may not be applied towards the 30 credits required for the M.S. degree.

Doctor of Philosophy in Earth and Environmental Science with Dissertation in Geology

Students of exceptional ability, as demonstrated in previous courses or in a master's degree program, may pursue a program leading to the doctoral degree.

The prospective doctoral candidate in Earth and environmental science with specialization in geology should develop a good background in geology, chemistry, physics, and mathematics, in addition to achieving a high level of competence in the field of specialization. Ph.D. students must include three credits of GEOL 592 and at least six credit hours of GEOL 593, unless the degree is completed in a shorter time. Additional information is found in the Graduate Catalog.

Research fields appropriate for the geology candidate include petrology, volcanology, mineral deposits, geochronology, stable isotopes, environmental geology, coal geology, geohydrology, sedimentation and stratigraphy, regional tectonics, and structural geology. Interdisciplinary programs in the Earth science fields are encouraged.

Geology Graduate Courses:

GEOL 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements.

Research under the guidance of a faculty member.

GEOL 503, Introduction to Soils, 3 cr, 2 cl hrs, 3 lab hrs

*Prerequisite: EARTH 202 or 203; or consent of instructor
Offered fall semester*

Introduction to soil formation, pedogenic processes, and soil description and mapping techniques. Shares lecture/lab with EARTH 405, but is graded separately and additional graduate-level work is required.

GEOL 507, Ore Deposit Seminar and Field Trip, 1–6 cr

Offered spring semester

Ore deposits and geology of a specific geographic area are studied in a weekly seminar and a one- to two-week field trip. The field trip will generally be international in alternate years. A paper is required. Students may register for the course more than once for a total of six credit hours.

GEOL 509, Soil Geomorphology, 3 cr, 2 cl hrs, 3 lab hrs

*Prerequisites: EARTH 202 and 403; or consent of instructor
Offered spring semester, alternate years*

Discussion of the use of soils to interpret the rate and timing of geomorphic processes and changing environmental parameters. Field trips. Shares lecture/lab with EARTH 409, but is graded separately and additional graduate-level work is required.

GEOL 512, 512D, Introduction to Geographic Information Systems, 3 cr, 2 cl hrs, 3 lab hrs

Offered Spring semester on demand

An introduction to the concepts of geographic information systems (GIS). Theoretical background to GIS; introduction to the nature and analysis of spatial data. ArcView and/or ArcGIS. Shares lecture with EARTH/ENVS 412, with additional expectations for graduate credit.

GEOL 524, Sedimentary Petrography, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Graduate standing

Offered spring semester, alternate years

Petrographic analysis and interpretation of sedimentary rocks, with emphasis on siliciclastics. Topics include: grain identification and provenance, identification of diagenetic minerals and textures, and interpretation of porosity and permeability characteristics. Shares lecture/lab with EARTH 424, but is graded separately and additional graduate-level work is required.

GEOL 525, Carbonate Sedimentology and Diagenesis, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructors

Offered fall semester, alternate years

This class covers the basics of carbonate sedimentation and diagenesis and looks at the evolution of carbonate sediments through geologic time (from Precambrian to recent). Included in the class are discussions of the impact of diagenesis on petroleum reservoir and aquifer potential. Shares lecture with EARTH 425 but is graded separately.

GEOL 528, Carbon Capture and Storage, 3 cr, 3 cl hrs

Prerequisite: Graduate standing and Math 132, Phys 122, Chem 122 or equivalents. Introductory geology course recommended but not required. Students from other departments (e.g. Petroleum Engineering, Chemistry, Physics, Mathematics) are encouraged to enroll.

Offered on demand.

The course examines efforts to reduce the buildup of atmospheric greenhouse gases by sequestering carbon into geological reservoirs. Topics include Earth's climate history, atmospheric chemistry, sources and sinks for greenhouse gases, carbon capture technology, geological reservoirs and seals, water/rock interaction, subsurface flow modeling, site monitoring for verification, decision making rationale, and policy issues. Taught jointly with the University of Utah using Distance Education facilities. Numerous guest lectures from experts in the field.

GEOL 530, Active Tectonics, 3 cr hrs

Prerequisites: EARTH 202, 203, or consent of instructor

Offered in alternate years

Study of Quaternary faults, including basic field techniques, tectonic geomorphology from fault scarps to mountain fronts, patterns of faulting, structural analysis of faults in alluvium, relation of surface to subsurface structures, paleoseismology, and review of Quaternary dating methods. Shares lecture/lab with EARTH 430, but is graded separately and additional graduate-level work is required.

GEOL 532, Interdisciplinary Field Research, 3 cr, 8 lab hrs

Prerequisite: Consent of instructor

Offered fall semester

Introduction to field-based research. Activities include proposal writing, data collection, interpretation, and preparation of a written report. Field work is an important part of the course, and hiking is required. The course is team-taught by several instructors. Shares lecture/lab with EARTH 432, but is graded separately, and additional graduate-level work is required.

GEOL 534, Introduction to Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS 122 or consent of instructor

Introduction to the theory and practical use of remotely sensed satellite images. Principles of radiation physics; sensor systems; data acquisition; image analysis; classification schemes. Remote sensing applications to atmospheric sciences, hydrology, mineral and oil exploration, natural hazards monitoring, and land and resources management. Become familiar with ERDAS Imagine remote sensing software. Laboratory exercises deal primarily with computer analysis of remotely-sensed images with some field exercises. Shares lecture/lab, with EARTH 434, with additional expectations for graduate credit. (Same as GEOP/HYD 534)

GEOL 536, Advanced Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 434 or HYD 534 or GEOL 534

This class deals with quantitative remote sensing for determination of the components of the energy balance (net radiation, latent and sensible heat fluxes, soil heat flux) and soil moisture, hyperspectral and multispectral image processing, radar and microwave imagery. In addition, advanced applications for geology, geophysics and geochemistry will be discussed. Shares lecture/lab with EARTH 436, with additional expectations for graduate credit. (Same as HYD 536)

GEOL 537, Volcanology Field Trip, 1-6 cr

Offered on demand

Field trip to study volcanic rocks in a specific area or volcanological process at an active volcano. Weekly seminars will precede a one- to two-week field trip. A paper is required. Students may register for the course more than once for a total of six credit hours. Shares lecture with EARTH 437, with additional expectations for graduate credit.

GEOL 538, Advanced Geographic Information Systems, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Consent of instructor

Advanced topics in geographic information systems (GIS) with a focus on applications in environmental sciences. Emphasis on theoretical aspects and practical applications of GIS science and technology and its integration with remote sensing data and field measurements. Computing exercises and programming projects utilizing GIS software. Discussion of GIS integration with environmental modeling. Shares lecture with ENVS 438, with additional expectations for graduate credit. (Same as HYD 538)

GEOL 540, Clastic and Carbonate Diagenesis, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Offered spring semester, alternate years

Discussion of clastic and carbonate diagenesis. Topics include: mineralogy and chemistry of authigenic minerals, rock-water interaction, mass transfer, influence of bacteria on diagenetic reactions, application of isotopes, diagenetic controls on porosity and permeability, and influence of depositional environment and detrital mineralogy on diagenesis.

GEOL 545, Petroleum Exploration Seismology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: PHYS 121 or equivalent; a 100-level EARTH course and associated lab; upper-class standing

Offered fall semester, odd-numbered years

An introductory course on seismic refraction and reflection imaging of the subsurface, with applications for petroleum, crustal and environmental problems. This course covers methods of data acquisition, processing, and interpretation. Topics include: survey geometries, data editing techniques, amplitude recovery, (bandpass) filtering, deconvolution, velocity analysis and migration, well log to seismic ties, contour maps, time-to-depth conversion. Designed for students with a range of Earth science and engineering backgrounds. Shares lecture with EARTH 445 with additional expectations for graduate credit.

GEOL 547, Depositional Systems and Basin Analysis, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Offered fall semester

Discussion of the spectrum of modern and ancient depositional environments and their relationships to tectonic settings.

GEOL 549, Astrobiology, 3cr, 3 cl hours

Prerequisites: graduate standing or consent of instructor.

Offered on demand

An in-depth and interdisciplinary study of astrobiology, including between living and non-living systems at multiple scales: stellar, planetary, meso, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principals of astrophysics and astronomy, geosciences and planetary science, chemistry and bioscience. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with EARTH/BIOLOG 449 (astrobiology), with additional expectations for graduate credit. Same as GEOC 549.

GEOL 550, 550D, Cave and Karst Systems, 3 cr, 3 cl hrs

Prerequisites: CHEM 121 & 122; and either any 100 level EARTH or BIOLOG 111

Offered spring semester, even years

A system-based study of caves and karstic terrains over time including formation mechanisms (speleogenesis), hydrology, geochemistry, mineralogy, and geomicrobiology. Emphasis on caves as interactive microcosms cross-cutting many disciplines. Shares lecture with EARTH 450, with additional expectations for graduate credit.

GEOL 550L, Cave and Karst Lab, 1 cr, 3 lab hrs

Offered spring semester, even years

Corequisite: GEOL 550

Survey of techniques applicable to various aspects of speleology and karst studies. Project-based lab, developed for each student in consultation with instructor. Shares lab with EARTH 450L, with additional expectations for graduate credit.

GEOL 551, Industrial Minerals, 3 cr, 3 cl hrs

Prerequisites: Graduate standing or consent of instructor

Offered alternate years

Study of basic concepts of production and use of industrial minerals in modern society. Emphasis on complex interactions between economics, geology, processing, marketing, and transportation. Selected industrial minerals studied in detail. Several field trips to operations and occurrences. (Same as ME 551)

GEOL 553 Intermediate Structural Geology, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EARTH 203; PHYS 121; MATH 131 or consent of instructor.

Offered alternate years.

For entering graduate students lacking undergraduate structural geology background. Elements of fault, fold, and rock mechanics; strain analysis and inference of stress in Earth's crust; construction of balanced, kinematically viable cross sections; brittle and ductile shear-sense indicators in faults and shear zones. Shares lecture and lab with EARTH 453, with additional expectations for graduate credit.

GEOL 554, Volcanology Seminar, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor.

Offered on demand

Seminar discussions of selected topics in volcanology.

GEOL 556, Volcanology, 3 cr, 2-3 cl hrs, 1-3 lab hrs

Prerequisite: EARTH 380 or consent of instructor

Offered on demand

Detailed studies of volcanic processes, pyroclastic rocks and mechanism of volcanic eruptions. Field trips to nearby volcanic fields. Shares lecture and field work with EARTH 456, with additional expectations for graduate credit.

GEOL 558, Mechanics of Earthquakes and Faulting, 3 cr, 3 cl hrs

Prerequisites: EARTH 453 or equivalent and graduate standing; or consent of instructor

Offered on demand

Observational and theoretical aspects of brittle failure in the Earth. Fracture mechanics; fault zone geometry and structure; earthquake sources; paleoseismic studies; seismic hazard assessments. (Same as GEOP 558)

GEOL 559, Geodynamics, 3 cr, 3 cl hrs

Prerequisites: Graduate standing or consent of instructor

Offered spring semester, even-numbered years

How does the Earth deform? Theory of mantle convection, rheology of the mantle and lithosphere, lithosphere deformation, heat transport in the Earth, and melting. Emphasis is on current controversies in geodynamics, and the formulation of mathematical models that explain the physical observations. Shares lecture with EARTH 459, with additional expectations for graduate credit. Same as GEOP 559.

GEOL 561, Reservoir and Caprock Analysis 3 cr, 2 cl hrs,
Prerequisite: Graduate standing or consent of instructor

Offered on demand

The class focuses on the role of sedimentary and structural heterogeneities in controlling porosity, permeability, and fluid flow in the subsurface. Topics include controls on conventional and unconventional reservoir quality and performance, evaluating caprock integrity, and the influence of faults and fracture networks on fluid flow. Applications to petroleum geology, petroleum engineering, carbon sequestration, and hydrology. There is a mandatory field trip associated with the class, which involves camping and moderately strenuous hiking on uneven ground. Shares lecture with EARTH 461, with additional expectations for graduate credit.

GEOL 566, Regional Tectonics, 3 cr, 3 cl hrs

Prerequisite: graduate standing or consent of instructor

Offered on demand

Study of major orogenic belts and processes of orogeny, with emphasis on the tectonic evolution of western North America. Fundamentals of plate tectonics, relationships between plate tectonics and orogeny.

GEOL 571, 571D, 572, 572D, Advanced Topics in Geology, 2-3 cr

Study of a special topic in geology, normally one related to a field of research at Tech.

GEOL 581, Directed Study, cr to be arranged

Study under the guidance of a member of the geology staff. In general, subject matter will supplement that available in the other graduate offerings in geology.

GEOL 590, Independent Study, cr to be arranged

Organized independent student research coordinated with a faculty member and documented in a final written report.

GEOL 591, Thesis (master's program), cr to be arranged

GEOL 592, Graduate Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered spring semesters

Seminar presentations by graduate students on their current research topics. M.S. students must present at least one seminar; Ph.D. students must present at least one seminar in each of two different semesters. Graded on S/U basis; credits earned may not be applied towards the 30 credits required for the M.S. degree. (Same as GEOB 592, GEOC 592, GEOP 592, HYD 592)

GEO 593, Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered fall and spring semesters

Seminar presentations by faculty, students, and outside speakers. Graded on S/U basis. Satisfactory performance consists of regular attendance at approved seminars. Credit earned may not be applied towards the 30 credits required for the M.S. degree. (Same as GEOB 593, GEOC 593, GEOP 593, HYD 593)

GEO 595, Dissertation (doctoral degree program), cr to be arranged

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Geobiology

Doctor of Philosophy in Earth and Environmental Science with Dissertation in Geobiology

Students of exceptional ability as demonstrated in previous courses or in a master's degree program may pursue a program leading to the doctoral degree.

The prospective doctoral candidate in Earth and environmental science with specialization in geobiology should develop a good background in chemistry, geology, mathematics, physics, and biology in addition to achieving a high level of competence in the field of specialization. Ph.D. students must include three credit hours of GEOB 592 and at least six credit hours of GEOB 593, unless the degree is completed in a shorter time. Additional information is found in the Graduate Catalog.

Fields of doctoral dissertation research include geomicrobiology, biogeochemical cycling, biologically mediated diagenesis, biological mineral precipitation and dissolution, isotopic geochemistry of biologically mediated processes, origin and early evolution of life, paleobiology, paleontology, and astrobiology. Interdisciplinary programs in the Earth science fields are encouraged.

Geobiology Graduate Courses:

GEOB 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements.

Research under the guidance of a faculty member.

GEOB 503, Advanced Geobiology, 3 cr, 3 cl hrs

Prerequisite: EARTH 201, CHEM 121, CHEM 122, BIOL 111, BIOL 112, or consent of instructor

Offered on demand

Consideration of the interactions between biology and the earth sciences on an advanced level. Microorganisms and metazoans have exerted enormous impact on the development of Earth's crust, oceans, and atmosphere over the course of the planet's history. In turn, the physical and chemical components of the planet have shaped the development of the biota and its evolution. In depth treatment of multiple lines of evidence including geochemical traces, fossil remains, molecular phylogenies, atmospheric and aqueous chemistries, and numerical modeling of relevant processes.

GEOB 592, Graduate Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered spring semesters

Seminar presentations by graduate students on their current research topics. M.S. students must present at least one seminar; Ph.D. students must present at least one seminar in each of two different semesters. Graded on S/U basis; credits earned may not be applied towards the 30 credits required for the M.S. degree (same as GEOC 592, GEOL 592, GEOP 592, HYD 592)

GEOB 593, Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered fall and spring semesters

Seminar presentations by faculty, students, and outside speakers. Graded on S/U basis. Satisfactory performance consists of regular attendance at approved seminars. Credit earned may not be applied towards the 30 credits required for the M.S. degree. (Same as GEOC 593, GEOL 593, GEOP 593, HYD 593)

GEOB 595, Dissertation (doctoral degree program), cr to be arranged.

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Geochemistry

Master of Science in Geochemistry

The Master of Science degree in Geochemistry may be earned either with thesis or without thesis in accordance with the general requirements of the Graduate Program.

The master's candidate must demonstrate competence in chemistry, geology, mathematics, and physics comparable to the requirements for the Bachelor of Science degree in either chemistry, one of the engineering sciences, or one of the geological sciences.

A program of study for the master's degree must be approved by the student's advisory committee and must satisfy the general requirements for the degree, including GEOC 590 (at least three credit hours) or GEOC 591 (at least six credit hours). Students must complete two credit hours of GEOC 592, at least four credit hours of GEOC 593 (unless the degree is completed in a shorter time), 12 credit hours in geochemistry, (which can also include EARTH 390 (Principles of Geochemistry)) and six credit hours in upper- division or graduate chemistry courses. As part of the degree requirements, students must have completed CHEM 331; GEOC 507, GEOC 544, EARTH 200 (mineralogy); or their equivalents.

Doctor of Philosophy in Earth and Environmental Science with Dissertation in Geochemistry

Students of exceptional ability as demonstrated in previous courses or in a master's degree program may pursue a program leading to the doctoral degree.

The prospective doctoral candidate in Earth and environmental science with specialization in geochemistry should develop a good background in chemistry, geology, mathematics, and physics in addition to achieving a high level of competence in the field of specialization. Ph.D. students must include three credit hours of GEOC 592 and at least six credit hours of GEOC 593, unless the degree is completed in a shorter time. Additional information is found in the Graduate Catalog.

Fields of doctoral dissertation research include geochemistry of ore deposits, trace element and isotope geochemistry of igneous and metamorphic systems, fluid-inclusion geochemistry, geochronology, hydrogeochemistry, stable isotope geochemistry, and environmental geochemistry. Interdisciplinary programs in the Earth science fields are encouraged.

Geochemistry Graduate Courses:

GEOC 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements.

Research under the guidance of a faculty member.

GEOC 507, Hydrogeochemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 122

Corequisite: EARTH 440

The thermodynamics and aqueous chemistry of natural waters, with emphasis on groundwater. Chemical equilibrium concepts, surface chemistry, redox reactions, and biochemistry. The interaction of water with the atmosphere and geologic materials. Basic concepts applied to problems of groundwater quality evolution, water use, and groundwater contamination. Shares lecture with EARTH 407, with additional expectations for graduate credit.

GEOC 516, ⁴⁰Ar/³⁹Ar Geochronology, 3 cr, 3 cl hrs

Prerequisite: EARTH 444 or consent of instructor

Offered fall semester

Principles and applications of ⁴⁰Ar/³⁹Ar geochronology and thermochronology, with applications to geologic systems.

GEOC 517, Advanced ⁴⁰Ar/³⁹Ar Geochronology, 3 cr, 3 cl hrs

Advanced topics, specialized applications, and current research in ⁴⁰Ar/³⁹Ar geochronology.

GEOC 531, Exploration Geochemistry, 3 cr, 2 cl hrs, 3 lab hrs

Pre- or Corequisite: EARTH 412 or equivalent

Offered spring semester on demand

An introduction to the generation, evaluation, and interpretation of geochemical datasets used in mineral exploration. Overview of trace element behavior in geologic environments. Sampling methodology and media, analytical techniques, data quality evaluation, and report writing. Field trip. Shares lecture with EARTH 431, with additional expectations for graduate credit.

GEOC 544, Principles of Isotope Geochemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 122; EARTH 200; EARTH 203

Offered spring semester

Principles of radiogenic isotope geochemistry and applications to geologic dating and to the petrogenesis of rock suites. Shares lecture with EARTH , with additional expectations for graduate credit.

GEOC 546, Contaminant Hydrology, 3 cr, 3 cl hrs

Prerequisite: EARTH 440, HYD 507

Corequisite: HYD 508

Offered alternate fall semesters

The physics, chemistry, and biology of inorganic, organic, and microbial contaminants in groundwater and surface water systems. Mechanisms by which contaminants are introduced. Transport and transformations of contaminants in surface waters, the vadose zone, and the saturated zones. Movement, capillary trapping, and solubility of relatively immiscible organic liquids. Contaminant isolation and remediation techniques. (Same as HYD 546.)

GEOC 549, Astrobiology, 3 cr, 3 cl hrs

Prerequisites: Graduate standing or consent of instructor.

Offered spring semester, even-numbered years

An in-depth and interdisciplinary study of astrobiology, including interactions between living and non-living systems at multiple scales: stellar, planetary, meso, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principles of astrophysics, geosciences, planetary science, chemistry, and biology. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with EARTH 449, with additional expectations for graduate credit. (Same as GEOL 549)

GEOC 550, Cave and Karst Systems, 3 cr, 3 cl hrs

Prerequisites: CHEM 121 & 122; and either any 100 level EARTH or BIOL 111

Offered spring semester, even years

A system-based study of caves and karstic terrains over time including formation mechanisms (speleogenesis), hydrology, geochemistry, mineralogy, and geomicrobiology. Emphasis on caves as interactive microcosms cross-cutting many disciplines. Shares lecture with EARTH 450, with additional expectations for graduate credit. Same as GEOL 550.

GEOC 550L, Cave and Karst Lab, 1 cr, 3 lab hrs

Offered spring semester, even years

Corequisite: GEOL/GEOC 550

Survey of techniques applicable to various aspects of speleology and karst studies. Project-based lab, developed for each student in consultation with instructor. Shares lab with EARTH 450L, with additional expectations for graduate credit. Same as GEOL 550L.

GEOC 565, Stable Isotope Geochemistry, 3 cr, 3 cl hrs

Offered fall semester

Principles of stable isotope geochemistry with applications to geologic systems.

GEOC 566, Practical Aspects of Mass Spectrometry, 3 cr, 1 cl hr, 6 lab hrs

Prerequisites: GEOC 565; consent of instructor

Offered spring semester

Theory and application of stable isotope mass spectrometry. Through lectures, problem sets, and laboratory exercises, students learn how to analyze geologic samples to determine stable isotope composition.

GEOC 567, Practical Aspects of Argon Mass Spectrometry, 2 cr, 2 cl hr

Prerequisites: GEOC 516 or consent of instructor

Offered spring semester

Theory and application of noble gas mass spectrometry. Through lectures, problem sets, and laboratory exercises, students obtain hands-on experience for analysis of geologic samples to determine sample age and/or thermal history. Each student conducts a research project and presents the results in written and oral reports.

GEOC 571, 571D, 572, 572D, Advanced Topics in Geochemistry, 2 or 3 cr

Study of a special topic in geochemistry, normally one related to a field of research at Tech.

GEOC 575, Theory and Practice of Electron Microprobe Analysis, 1 cr

Prerequisites: EARTH 380; consent of instructor

Principles, techniques and applications of electron microprobe analysis of geological samples. Required for students who will use the electron microprobe as part of their research. Includes lecture and hands-on sample preparation and analysis.

GEOC 581, Directed Study, cr to be arranged

Study under the guidance of a member of the geochemistry staff. In general, subject matter will supplement that available in the other graduate offerings in geochemistry.

GEOC 590, Independent Study, cr to be arranged

Organized independent student research coordinated with a faculty member and documented in a final written report.

GEOC 591, Thesis (master's program), cr to be arranged

GEOC 592, Graduate Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered spring semesters

Seminar presentations by graduate students on their current research topics. M.S. students must present at least one seminar; Ph.D. students must present at least one seminar in each of two different semesters. Graded on S/U basis; credits earned may not be applied towards the 30 credits required for the M.S. degree (same as GEOB 592, GEOL 592, GEOP 592, HYD 592)

GEOC 593, Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered fall and spring semesters

Seminar presentations by faculty, students, and outside speakers. Graded on S/U basis. Satisfactory performance consists of regular attendance at approved seminars. Credit earned may not be applied towards the 30 credits required for the M.S. degree. (Same as GEOB 593, GEOL 593, GEOP 593, HYD 593)

GEOC 595, Dissertation (doctoral degree program), cr to be arranged.

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Geophysics (Solid Earth)

The Geophysics program offers an undergraduate degree in Earth Science with Geophysics option. See page 52.

Graduate Program

Requirements for the Master of Science in Geophysics (Solid Earth)

The Master of Science degree in Geophysics (Solid Earth) may be earned under either of the plans outlined below:

With Thesis:

The student's course of study must be approved by the advisory committee and must fulfill the general requirements for the master's degree with thesis and must include (unless taken in undergraduate work): EARTH 325, 445, and 448, or their equivalents; upper-division geology, six credit hours; competence in mathematics corresponding to nine credit hours beyond calculus; at least six credit hours of GEOP 591, two credit hours of GEOP 592, at least four credit hours of GEOP 593, unless the degree is completed in a shorter time, and twelve additional credit hours in graduate geophysics (up to six credit hours of this requirement may be replaced with non-geophysics graduate courses with the advisor's approval).

Without Thesis:

Courses approved by the student's advisory committee must fulfill the general requirements for the master's degree without thesis and must include (unless taken in undergraduate work): EARTH 325, 445, and 448, or their equivalents; upper-division geology, six credit hours; competence in mathematics corresponding to nine credit hours beyond calculus; at least three credit hours of GEOP 590, two credit hours of GEOP 592, at least four credit hours of GEOP 593, unless the degree is completed in a shorter time, and twelve additional credit hours of graduate courses in geophysics (up to six credit hours of this requirement may be replaced with non-geophysics graduate courses with the advisor's approval).

Doctor of Philosophy in Earth and Environmental Science with Dissertation in Geophysics

Students of exceptional ability as demonstrated by previous academic achievement may pursue a program leading to the doctoral degree.

The prospective doctoral candidate in Earth and environmental science with specialization in physics of the solid Earth should develop a solid background in physics, mathematics, and geology in addition to achieving a high level of competence in the field of geophysics.

With the approval of the advisory committee, the student should select a program including a minimum of nine credit hours in graduate geophysics beyond the M.S. degree, three credit hours of GEOP 592, at least four credit hours of GEOP 593, unless the degree is completed in a shorter time, plus additional courses in related fields.

Research fields appropriate for the geophysics candidate include crustal exploration, earthquake seismology, tectonophysics, environmental, and hydrogeothermal studies. Interdisciplinary programs in the Earth science fields are encouraged.

Geophysics Graduate Courses:

GEOP 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements.

Research under the guidance of a faculty member.

GEOP 505, 505D, Analysis of Time Series and Spatial Data, 3 cr, 3 cl hrs

Offered in alternate years

An introductory overview of methods for analyzing temporal and spatial series with an emphasis on scientific applications. Linear systems in continuous and discrete time, Fourier analysis, spectral estimation, convolution and deconvolution, filtering, the z and Laplace transforms, stationary and nonstationary time series, ARIMA modeling, forecasting, and generalizations to multidimensional and multichannel applications. (Same as MATH 587 and HYD 587)

GEOP 523, 523D, Theoretical Seismology, 3 cr, 3 cl hrs

Offered in alternate years

Linear elastic wave theory including reflection and refraction of elastic waves, propagation of body and surface waves, free oscillations of an elastic sphere, seismic rays in a spherically-stratified Earth, and earthquake mechanisms.

GEOP 524, Observational Seismology, 3 cr, 3 cl hrs

Offered in alternate years

Techniques and methods in earthquake seismology including seismometry and seismic networks, earthquake location, earthquake statistics, strong-motion seismology, and seismic source parameters.

GEOP 529, 529D, Geophysical Inverse Methods, 3 cr, 3 cl hrs

Offered in alternate years

Theory and practice of the various techniques of inverting geophysical data to obtain models. Primary emphasis is on the understanding and use of linear inverse techniques. (Same as MATH 519)

GEOP 534, Introduction to Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS 122 or consent of instructor

Introduction to the theory and practical use of remotely sensed satellite images. Principles of radiation physics; sensor systems; data acquisition; image analysis; classification schemes. Remote sensing applications to atmospheric sciences, hydrology, mineral and oil exploration, natural hazards monitoring, and land and resources management. Laboratory exercises deal primarily with computer analysis of remotely-sensed images with some field exercises. EARTH 434 and GEOP 534 share lecture/lab, but GEOP 534 is graded separately and additional graduate-level work is required. (Same as GEOL/HYD 534)

GEOP 545, Petroleum Exploration Seismology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: PHYS 121 or equivalent; a 100-level EARTH course and associated lab; upper-class standing

Offered fall semester, odd-numbered years

An introductory course on seismic refraction and reflection imaging of the subsurface, with applications for petroleum, crustal and environmental problems. This course covers methods of data acquisition, processing, and interpretation. Topics include: survey geometries, data editing techniques, amplitude recovery, (bandpass) filtering, deconvolution, velocity analysis and migration, well log to seismic ties, contour maps, time-to-depth conversion. Designed for students with a range of Earth science and engineering backgrounds. Shares lecture with EARTH 445 with additional expectations for graduate credit.

GEOP 558, Mechanics of Earthquakes and Faulting, 3 cr, 3 cl hrs

Prerequisites: EARTH 453 or equivalent and graduate standing; or consent of instructor

Offered on demand

Observational and theoretical aspects of brittle failure in the Earth. Fracture mechanics; fault zone geometry and structure; earthquake sources; paleoseismic studies; seismic hazard assessments. (Same as GEOL 558)

GEOP 559, Geodynamics, 3 cr, 3 cl hrs

Prerequisites: Graduate standing or consent of instructor

Offered spring semester, even-numbered years

How does the Earth deform? Theory of mantle convection, rheology of the mantle and lithosphere, lithosphere deformation, heat transport in the Earth, and melting. Emphasis is on current controversies in geodynamics, and the formulation of mathematical models that explain the physical observations. Shares lecture with EARTH 459 with additional expectations for graduate credit. Same as GEOL 559.

GEOP 570, Current Topics in Earthquake Seismology, 3 cr, 3 cl hrs

Prerequisite: consent of instructor

Offered on demand

A seminar of current research topics in earthquake seismology with an emphasis on the critical review of recently published papers and preprints.

GEOP 571, 572, Advanced Topics in Geophysics, 2–3 cr each semester

Offered on demand

Study of advanced topics in geophysics.

GEOP 581, Directed Study, cr to be arranged

Study under the guidance of a member of the graduate faculty. In general, subject matter will supplement that available in the other graduate course offerings.

GEOP 590, Independent Study, cr to be arranged

Organized independent student research coordinated with a faculty member and documented in a final written report.

GEOP 591, Thesis (master's program), cr to be arranged**GEOP 592, Graduate Seminar, 1 cr, 1 cl hr**

Prerequisite: Graduate standing

Offered spring semesters

Seminar presentations by graduate students on their current research topics. M.S. students must present at least one seminar; Ph.D. students must present at least one seminar in each of two different semesters. Graded on S/U basis; credits earned may not be applied towards the 30 credits required for the M.S. degree (same as GEOB 592, GEOL 592, GEOC 592, HYD 592)

GEOP 593, Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered fall and spring semesters

Seminar presentations by faculty, students, and outside speakers. Graded on S/U basis. Satisfactory performance consists of regular attendance at approved seminars. Credit earned may not be applied towards the 30 credits required for the M.S. degree. (Same as GEOB 593, GEOC 593, GEOL 593, HYD 593)

GEOP 595, Dissertation (doctoral degree program), cr to be arranged

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Hydrology

The Hydrology program offers an undergraduate degree in Earth Science with Hydrology option. See page 52.

Graduate Program

Master of Science in Hydrology

The Master of Science degree in Hydrology requires completion of a thesis according to the general requirements of the Graduate Program.

The student's course of study must be approved by the advisory committee and must fulfill the general requirement for the master's degree and must include:

- EARTH 440, HYD 507, 508, 510, 547
- Six credits from the following: EARTH 441, EARTH 442, EARTH 443, HYD 531, HYD 532, HYD 533, HYD 541, HYD 542, HYD 543, HYD 544, or other approved 1-credit HYD courses
- HYD 591 (at least six credit hours)
- HYD 592 (two credit hours) and HYD 593 (four credit hours); credits do not apply to the 30 hours required for the M.S. degree.
- EARTH 202 or equivalent
- MATH 283 or 382 or equivalent
- At least three additional graduate-level course credits approved by the advisory committee.
- The Institute Graduate Degree Requirements must also be satisfied

Examples of courses other than hydrology which are appropriate for graduate programs in hydrology include, but are not limited to: BIOL 343, 446; CHEM 331, 332, 333, 334; EARTH 370, 403, 409, 444, 445, 448, 460; GEOL 503, 509, 547, 553; GEOP 505, 529; MATH 332, 382, 384, 410, 411, 415, 430, 435, 436, 438, 483, 486, 488, 511, 512, 533, 586, 587; PETR 445, 523, 544, 546, 564; PHYS 421, 526.

Master of Science in Hydrology Options in Petroleum and Environmental Geofluids

The Geofluids option offers multidisciplinary course curricula leading to the Master of Science Degree in Hydrology with tracks in Petroleum or Environmental studies.

The student's course of study must be approved by the advisory committee and must fulfill the general requirement for the master's degree and must include:

- EARTH 440 and 440L, EARTH 441, EARTH 460, HYD 508, HYD 510, HYD 591, HYD 592.

Geofluids Petroleum Track

- Nine credits from the following: EARTH 325, EARTH 445, GEOL 547, GEOP 546, PETR 370, PETR 345, PETR 445, PETR 546

Geofluids Environmental Track

- Nine credits from the following: EARTH 325, EARTH 422, GEOL 509, HYD 507, HYD 532, HYD 538, HYD 541, HYD 544, HYD 546, HYD 547, HYD 558.

Doctor of Philosophy in Earth and Environmental Science with Dissertation in Hydrology

Students of exceptional ability as demonstrated in previous courses or in a master's degree program may pursue a program leading to the doctoral degree.

The prospective doctoral candidate in Earth and environmental science with specialization in hydrology should develop a good background in physics, mathematics, chemistry, and geology in addition to achieving a high level of competence in the field of specialization.

With approval of the advisory committee, the student should select a program including a minimum of nine credits in graduate hydrology beyond the M.S. degree, three credits of HYD 592, six credits of HYD 593, plus additional courses in related fields. Some appropriate courses are given under the Master of Science degree requirements.

Research fields appropriate for the doctoral candidate include regional hydrology, groundwater recharge, vadose zone hydrology, stochastic subsurface hydrology, hydrogeochemistry, isotope hydrology, hydroclimatology, pollutant transport, aquifer restoration, multi-phase flow of immiscible fluids, deterministic and stochastic numerical aquifer simulation, finite difference and finite element numerical methods, and field instrumentation. Interdisciplinary programs in the Earth science fields are encouraged.

Graduate Certificate Program in Hydrology

The Hydrology Certificate program is aimed at working professionals or students who wish to increase their qualifications in Hydrology outside of a degree program. The program covers fundamentals of atmospheric, surface, and subsurface hydrology while leaving flexibility to focus on related areas of particular individual interest. The Certificate requires a minimum of 15 credit hours of graduate and upper division course work as follows:

- EARTH 440 (3), EARTH 441 (1), EARTH 442 (1), EARTH 443 (1)
- HYD 510 (3)
- Additional credits of advisor-approved graduate-level coursework (6)

Hydrology Graduate Courses:

HYD 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements.

Research under the guidance of a faculty member.

HYD 507, Hydrogeochemistry, 3 cr, 3 cl hrs

Prerequisite: CHEM 122

Pre- or Corequisite: EARTH 440

Offered fall semesters

The thermodynamics and aqueous chemistry of natural waters, with emphasis on groundwater. Chemical equilibrium concepts, surface chemistry, redox reactions, and biochemistry. The interaction of water with the atmosphere and geologic materials. Basic concepts applied to problems of groundwater quality evolution, water use, and groundwater contamination. Shares lecture with EARTH 407, with additional expectations for graduate credit. (Same as CHEM 531 and GEOC 507.)

HYD 508, Flow and Transport in Hydrologic Systems, 4 cr, 3 cl hrs, 3 lab/recitation hrs

Prerequisites: EARTH 440, 440L and 510

Offered spring semester

Principles of flow and transport in hydrological systems, including rivers, lakes, aquifers, the vadose zone, glaciers and the lower atmosphere. Fluid mechanical and thermodynamic properties, fluid statics, fluid dynamics, including mass, momentum and energy conservation, and transport of heat, particles and non-reactive chemicals with fluid flow. Single and multiphase laminar flow in porous and fractured permeable media. Turbulence and related topics that are of particular interest to hydrologists.

HYD 510, 510D, Quantitative Methods in Hydrology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: MATH 231; Pre or Corequisite EARTH 440

Offered fall semester

Introduction to the methods of mathematical physics used in hydrologic science. Presented in the context of mathematical models of water and energy balances, fluid flow, and heat & solute transport. Application to aquifers, the vadose zone, land-surface runoff, rivers, and the atmospheric boundary layer. Methods span advanced engineering calculus, including numerics and differential equations. Use of software (Matlab, Maple, and COMSOL Multiphysics) for problem solving and solution presentation. Programming with Matlab.

HYD 531, 531D, Aquifer Mechanics, 1 cr, 1 cl hr

Prerequisite: EARTH 440 and 440L

Offered spring semester

Physics of flow to wells, steady-state and transient solutions to well hydraulics equations, image well theory, responses of aquifers to perturbations.

HYD 532, 532D, Vadose Zone Dynamics, 1 cr, 1 cl hr

Prerequisite: EARTH 440, 440L, 442, HYD 510 or consent of instructor

Offered spring semester

Physical processes governing fluid, solute, heat, and gas transport through the vadose zone; plant water uptake; applications of the model HYDRUS1D for the evaluation of these physical processes.

HYD 533, 533D, Runoff and Flood Processes, 1 cr, 1 cl hr

Corequisite: EARTH 440 and 440L or HYD 510

Offered spring semester

Processes leading to runoff formation in watersheds and the transformation of a flood pulse through a channel network system. Emphasis on physical mechanisms and their treatment in models, as well as observations made in the field.

HYD 534, 534D, Introduction to Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS 122 or consent of instructor

Introduction to the theory and practical use of remotely sensed satellite images. Principles of radiation physics; sensor systems; data acquisition; image analysis; classification schemes. Remote sensing applications to atmospheric sciences, hydrology, mineral and oil exploration, natural hazards monitoring, and land and resources management. Become familiar with ERDAS Imagine remote sensing software. Laboratory exercises using ERDAS Imagine deal primarily with computer analysis of remotely sensed images with some field exercises. Shares lecture/lab with EARTH 434, with additional expectations for graduate credit. (Same as GEOL/GEOP 534)

HYD 535, Engineering and Science Applications of Vadose Zone Modeling, 1 cr, 1 cl hr

Prerequisites: EARTH 440, EARTH 442, HYD 510 or consent of instructor

Application of the HYDRUS models in 1, 2, and 3-dimensions, and COMSOL Multiphysics, for the evaluation of variably saturated flow and transport. After an introduction to the HYDRUS models, hydrology and engineering students will work on their own HYDRUS application dealing with typical geotechnical, agricultural, and ecohydrological simulations including slope stability, drainage through tailings and rock piles, hazardous waste migration, soil moisture controls on evapotranspiration and vegetation growth.

HYD 536, Advanced Remote Sensing, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 434 or HYD 534 or GEOL 534

Offered on demand

This class deals with quantitative remote sensing for determination of the components of the energy balance (net radiation, latent and sensible heat fluxes, soil heat flux) and soil moisture, hyperspectral and multispectral image processing, radar and microwave imagery. In addition, advanced applications for geology, geophysics and geochemistry will be discussed. Shares lecture/lab with EARTH 436, with additional expectations for graduate credit. (Same as GEOL 536)

HYD 538, Advanced Geographic Information Systems, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Consent of instructor

Advanced topics in geographic information systems (GIS) with a focus on applications in environmental sciences. Emphasis on theoretical aspects and practical applications of GIS science and technology and its integration with remote sensing data and field measurements. Computing exercises and programming projects utilizing GIS software. Discussion of GIS integration with environmental modeling. Shares lecture/lab with ENV 438, with additional expectations for graduate credit. (Same as GEOL 538)

HYD 541, 541D, Water Resources Management, 1 cr, 1 cl hr

Prerequisite: EARTH 440 and 440L

Offered alternate spring semesters

Social and economic basis for administering water. Comparison of American Indian and European attitudes toward the hydrological system. Fundamentals of water law and policy in the United States.

HYD 542, 542D, Hillslope Hydrology, 1 cr, 1 cl hr

Prerequisites: EARTH 440, 440L, 442, HYD 510, HYD 532 or consent of instructor

Physical processes governing water flow through hillslope systems and into receiving streams.

HYD 543, 543D, Ecohydrology, 1 cr, 1 cl hr

Prerequisites: EARTH 440 and 440L

Interactions between terrestrial plants and water, nutrients, and light resources in semiarid environments. Ecohydrological processes, dynamics, and simple numerical models.

HYD 544, 544D, Groundwater Remediation, 1 cr, 1 cl hr

Prerequisites: EARTH 440, HYD 507, HYD 510

Pre- or corequisite EARTH 441

Offered alternate spring semesters

Coverage of accepted and emerging techniques to remove or control groundwater contaminants. Emphasis is placed on the suitability of techniques for dealing with inorganic, organic, and biological contaminants of differing properties. Evaluation of the current and projected regulatory environment as a driver for groundwater cleanup.

HYD 546, 546D, Contaminant Hydrology, 3 cr, 3 cl hrs

Prerequisites: EARTH 440; HYD 507

Pre- or Corequisite: HYD 508

Offered alternate fall semesters

The physics, chemistry, and biology of inorganic, organic, and microbial contaminants in groundwater and surface water systems. Mechanisms by which contaminants are introduced. Transport and transformations of contaminants in surface waters, the vadose zone, and the saturated zones. Movement, capillary trapping, and solubility of relatively immiscible organic liquids. Contaminant isolation and remediation techniques. (Same as GEOC 546.)

HYD 547, Hydrological Modeling, 3 cr, 3 cl hrs

Prerequisites: EARTH 440, HYD 508, HYD 510

Analysis and synthesis of issues in hydrologic science. Related engineering problem solving. Conceptual modeling process: model conceptualization and parameterization, model diagnosis, testing and validation, and model prediction. Conceptual models for testing scientific hypotheses, assimilating data, developing policy, and solving engineering design and operational problems. Applications to land-surface, surface water, vadose zone, and groundwater, singly and together, and to their interfaces with the atmosphere and oceans.

HYD 548, Laboratory and Field Methods in Hydrology, 3 cr, 1 cl hr, 6 lab hrs

Prerequisite: Consent of instructor

Offered on demand

Instrumentation and methodologies used in hydrological investigations in a field or laboratory setting. Course topics may range across a variety of physical and chemical hydrological techniques in vadose, groundwater and surface hydrology. Examples of potential topical areas include, but are not limited to, aquifer, lake and stream sample collection, storage and analysis, aquifer and watershed characterization, discharge measurements and tracer tests, land surface-atmosphere flux measurements, and hydrologic field campaigns.

HYD 552, Fluid/Surface Interactions, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Offered in alternate years

The physics and chemistry of interfaces, focusing on the behavior of multifluid systems both in the presence and absence of solids. How basic interactions among microscopic particles can explain macroscopic phenomena. Application-oriented, focusing on interactions important in hydrology, petroleum engineering, and environmental engineering. (Same as PETR 552)

HYD 554, Environmental Physics for Evapotranspiration, 3 cr, 3 cl hrs

Prerequisites: EARTH 440; HYD 508; or consent of instructor.

The first part of the course includes elements of environmental physics: radiation balance of the Earth's surface; transfer of momentum, heat, and mass; and crop micrometeorology. The second part focuses on vegetation water use and evapotranspiration: measurement methods; evaluation from meteorological observations; and prediction of spatial and temporal distribution of regional evapotranspiration using remote sensing.

HYD 555, Advanced Aqueous Geochemistry, 3 cr, 3 cl hrs

Prerequisite: HYD 507 or consent of instructor

Advanced topics in aqueous geochemistry, including chemical weathering, surface reactivity, colloidal phenomena, environmental organic chemistry, process-based reactive transport modeling, and other topics of interest to those enrolled. The course consists of introductory lectures on each topic followed by review and discussion of current papers from the literature.

HYD 558, Environmental Tracers in Hydrology, 3 cr, 3 cl hrs

Prerequisites: EARTH 440; HYD 507

Offered in alternate years

Atomic structure and abundances of environmental isotopes. Stable isotope fractionation. Mass spectrometry. Applications of the stable isotopes of hydrogen, oxygen, and carbon to meteorology and hydrology. Radioactive decay and radionuclide production. Applications of tritium, ^3He , ^{14}C , ^{36}Cl , and other radionuclides. Application of Cl^- , Br , chlorofluorocarbons and other environmental tracers to hydrologic problems.

HYD 560, Applied Groundwater Hydrology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: HYD 508

Offered on demand

Topics for in-depth investigation may include well design, aquifer pumping test design and interpretation, groundwater flow simulation, and aquifer contamination. Field experiments, field trips, lab analysis, computer work, technical report preparation, and oral presentations.

HYD 570, Seminar in Hydrology, 2 cr, 2 cl hrs

Review and discussion of papers relating to hydrology.

HYD 571, 571D, 572, Advanced Topics in Hydrology, 1–3 cr each semester

Offered on demand

Study of special topics in hydrology.

HYD 581, Directed Study, cr to be arranged

Study under the guidance of a member of the graduate faculty. In general, subject matter will supplement that available in the other graduate course offerings.

HYD 587, Analysis of Time Series and Spatial Data, 3 cr, 3 cl hrs

Offered in alternate years

An introductory overview of methods for analyzing temporal and spatial series with an emphasis on scientific applications. Linear systems in continuous and discrete time, Fourier analysis, spectral estimation, convolution and deconvolution, filtering, the z and Laplace transforms, stationary and nonstationary time series, ARIMA modeling, forecasting, and generalizations to multidimensional and multichannel applications. (Same as MATH 587 and GEOP 505)

HYD 590, Independent Study, cr to be arranged

Organized independent student research coordinated with a faculty member and documented in a final written report.

HYD 591, Thesis (master's program), cr to be arranged

HYD 592, Graduate Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered spring semesters

Seminar presentations by graduate students on their current research topics. M.S. students must present at least one seminar; Ph.D. students must present at least one seminar in each of two different semesters. Graded on S/U basis; credits earned may not be applied towards the 30 credits required for the M.S. degree (same as GEOB 592, GEOL 592, GEOC 592, GEOP 592)

HYD 593, Seminar, 1 cr, 1 cl hr

Prerequisite: Graduate standing

Offered fall and spring semesters

Seminar presentations by faculty, students, and outside speakers. Includes both Department and hydrology-specific seminars. Graded on S/U basis. Satisfactory performance consists of regular attendance at approved seminars. Credit earned may not be applied towards the 30 credits required for the M.S. degree. (Same as GEOB 593, GEOC 593, GEOL 593, GEOP 593)

HYD 595, Dissertation (doctoral degree program), cr to be arranged

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Faculty Research Interests

- Axen—Continental Tectonics, Fault Mechanics, and Geothermal Resources
- Bilek—Earthquake Rupture Processes, Stresses and Structure of Fault Zones, Shallow Subduction Zone Processes, Tsunami
- Boston—Caves, Karst Systems, Geomicrobiology, Extremophile Organisms, Geobiochemical Cycling, Astrobiology, Robotic and Human Exploration of Other Planets, Comparative Planetology, Evolutionary Implications of Conjoined Organic/Cybernetic Devices
- Cadol—Surface Water Hydrology, Ecohydrology, Fluvial Geomorphology
- Condie—Trace Element and Isotope Geochemistry, Precambrian Studies
- Harrison—Soil Properties, Recurrence Intervals of Earthquakes, Soil Salinization in Arid Environments, Soil Stability
- Hendrickx—Vadose Zone Hydrology, Remote Sensing of Energy Balance, Soil Physics, Environmental Biophysics
- Kyle—Igneous Geochemistry, Antarctic Geology, Volcanology
- McIntosh—Cenozoic Volcanism, Paleomagnetism, Antarctic Studies, Argon Dating
- Mozley—Environmental Geology, Sedimentary Petrology, Low-Temperature Geochemistry, Carbon Sequestration
- Murray—Crustal Deformation and Rheology, Geodetic Measurements, Earthquake and Volcano Hazards
- Person—Paleohydrology, Basin-Scale Numerical Modeling, Geothermal Systems, Carbon Sequestration, Role of Groundwater in Geologic Processes
- Phillips—Groundwater Chemistry, Isotope Hydrology, Groundwater Dating, Quaternary Studies
- Reusch—Polar climates and climate change through meteorology, ice cores, sea ice, climate modeling and artificial neural network techniques.
- Spinelli—Marine Hydrogeology and Heat Flow, Groundwater-Surface Water Interactions, Sediment Physical Properties
- Ulmer-Scholle—Carbonate Diagenesis; Sedimentary Petrography, Fluid Inclusions and Thermal and Fluid Histories of Carbonate Basins, Carbonate Depositional Environments, Carbon Sequestration, Computer-Based Applications and Geological Training
- Wilson—Groundwater Hydrology, Numerical and Analytical Modelling, Stochastic Hydrology, Colloid and Bacteria Transport

Adjunct Faculty Research Interests

Bauer—Structural Geology and Tectonics, Precambrian Geology
 Broadhead—Petroleum Geology, Stratigraphy
 Cather—Clastic and Volcaniclastic Sedimentology, Basin Analysis, Regional Tectonics
 Chamberlin—Ignimbrite Calderas of Central New Mexico, Structure & Stratigraphy of Central Rio Grande Rift
 Chapin—Volcanology, Tectonics, Economic Geology
 Connell—Neogene and Quaternary Geology and Stratigraphy, Geomorphology
 Creech-Eakman—Characterization of Exoplanet Atmospheres and Associated Planetary Properties (NESSI—New Mexico Tech Extrasolar Spectroscopic Survey Instrument); Mid-infrared Imaging, Spectroscopy and Optical Interferometry; Pulsation and Dust Production in Mira Variables
 Dunbar—Igneous Petrology, Volcanology, Trace Element Behavior in High- and Low-Temperature Aqueous Systems, Microprobe Geochemical Analysis
 Hawley—Geomorphology, Quaternary Stratigraphy, Environmental Geology, Hydrogeology
 Heizler— $^{40}\text{Ar}/^{39}\text{Ar}$ Thermochronology
 J. Johnson—Volcanology, eruptive processes, integrated geophysical measurements, numerical modeling
 Kelley—Fission-Trace Thermochronology, Tectonics, Thermal Studies
 Kieft—Geomicrobiology of Soils and Subsurface Environments
 Land—Cave and Karst Hydrology, Hydrogeology
 Love—Environmental Geology, Quaternary Geology, Sedimentology
 McCord—Vadose Zone Hydrology, Numerical Modeling, Stochastic Hydrology
 McLemore—Economic Geology
 Pullin—Aqueous environmental chemistry; natural organic carbon and metal ions in the environment; analytical methods for natural waters.
 Reiter—Geothermics, Hydrogeothermics, Crustal Geodynamics
 Rowe—Volcano and Structural Seimology, Signal Processing
 Scholle—Carbonate Sedimentology and Petroleum Geology; Controls on Diagenesis and Porosity in Chalks; Paleozoic Carbonates of New Mexico
 Stephens—Hydrogeology, Unsaturated Flow, Groundwater Flow Modeling
 Tidwell—Fluid Flow, Solute Transport, Media Heterogeneity, Laboratory Technologies, and Water Resources Management

Timmons—NM StateMap Manager, Field Geology, Structural Geology and Tectonics
 Vivoni—Hydrometeorology, Watershed Modeling, Surface Hydrology, Ecohydrology, Environmental Fluid Mechanics, Turbulence

Emeritus Faculty Research Interests

Budding—Metamorphic Petrology, Geotectonics
 Campbell—Metallic Ore Deposits, Stable Isotope Geochemistry, Carbon Sequestration
 G. Gross—Electrical and Electrochemical Properties of Ice, Isotope Hydrology, Geophysics, Desert Geomorphology
 D. Johnson—Biostratigraphy, Paleozoic Depositional Environments
 Lattman—Geomorphology, Remote Sensing
 Sanford—Earthquake Seismology, Crustal Exploration, Tectonophysics, Geophysical Methods for Shallow Exploration
 Schlue—Seismology, Surface Waves, Rift Studies, Inverse Methods

Environmental Science

Environmental Science Advisory Committee:

Dr. Michael Pullin, Chemistry

Dr. Bruce Harrison, Earth and Environmental Science

Dr. Rebecca Reiss, Biology

Dr. Clint Richardson, Environmental Engineering

Many faculty at New Mexico Tech have an interest in the application of their research to environmental problems. Their research interests are listed in the appropriate departmental section of the catalog.

Degrees Offered: B.S. in Environmental Science with Options in Biology, Chemistry, Geology, Hydrology, and Instrumentation and Measurements

The Bachelor of Science degree in Environmental Science draws upon courses from biology, chemistry, Earth science, physics, and environmental engineering. Students must be aware of the complexity of environmental problems, yet have a rigorous background to address specific aspects of those problems. To ensure that graduates are competitive in the marketplace for diverse environmentally oriented careers, Environmental Science students take classes in all of the disciplines listed above. They additionally select a specialization in biology, chemistry, geology, hydrology, or instrumentation and measurements. Each option is sufficiently in-depth to allow students to continue their education in a traditional graduate program within that discipline, should they choose.

An advisory committee, composed of faculty from the specific disciplines, is convened to help students plan their programs.

Undergraduate Program

Core Requirements for the Bachelor of Science Degree in Environmental Science

In addition to the General Education Core Curriculum Requirements (page 7) the following core program is required of all Environmental Science students:

- BIOL 331 (3), 343 & 343L (4)
- CHEM 311 & 311L (4), 333 & 333L (4), 422 & 422L (4)
- A 100-level EARTH course and associated lab (4)
- EARTH 201 & 201L (4), EARTH 202 & 202L (4), EARTH 440 (4)
- MATH 231 (4), 283 (3)
- ENVS 472 (1)

- All students in the Environmental Science program are required to attend the Environmental Science Senior Seminar (ENVS 472) for four years or, if transfer students, for the duration of their enrollment in the Environmental Science program. In the first three years, students need only audit the seminar, but in their senior year, they are required to present at the seminar and take the class for a grade.
- Three credit hours of courses numbered 491 and 492 taken in the appropriate department in the subject area of environmental science. These credit hours shall comprise a supervised research project, supervised scholarship project, or a supervised internship, and must result in a written paper or senior thesis. Prior to beginning the research project or internship, the student must prepare a short proposal of the activity. This proposal must be approved by the student's advisor and two faculty from the Environmental Science Advisory Committee. Following completion of the project, all three faculty must sign off on the resulting research paper.

Bachelor of Science in Environmental Science with Biology Option

Minimum credit hours required—135

In addition to the General Degree Requirements (page 7), and the core Environmental Science Requirements (above), the following courses are required:

- BIOL 112 & 112L (4), 311 & 311L (4), 333 & 333L (4)
- Technical Electives (12)—Technical electives to be approved by the Advisory Committee

Bachelor of Science in Environmental Science with Chemistry Option

Minimum credit hours required—135

In addition to the General Degree Requirements (page 7), and the core Environmental Science Requirements (above), the following courses are required:

- CHEM 331 & 331L (4), 334 & 334L (4), 411 & 411L (4)
- Technical Electives (14)—Recommended technical electives, which must be approved by the advisory committee, include CHEM 332, 441, 442

Bachelor of Science in Environmental Science with Geology Option

Minimum credit hours required—135

In addition to the General Degree Requirements (page 7), and the core Environmental Science Requirements above), the following courses are required:

- EARTH 203 & 203L (4), EARTH 204 & 204L (4), EARTH 380 (3), EARTH 385 (3), EARTH 405 (3)
- Electives to meet minimum credit hours required.

Bachelor of Science in Environmental Science with Hydrology Option

Minimum credit hours required—135

In addition to the General Degree Requirements (page 7), and the core Environmental Science Requirements (above), the following courses are required:

- EARTH 204 & 204L (4), EARTH 340 (3), EARTH 440 (4), EARTH 441 (1), EARTH 442 (1), EARTH 443 (1)
- MATH 335 (3)
- Electives to meet minimum credit hours required.

Bachelor of Science in Environmental Science with Instrumentation and Measurements Option

Minimum credit hours required—135

In addition to the General Degree Requirements (page 7), and the core Environmental Science Requirements (above), a minimum of 25 credit hours from the following (at least 17 credit hours must be numbered 300 or above) are required:

- ES 332 (3)
- EE 211 (3), 212 & 212L (4), 231 & 231L (4), 308 & 308L (4), 321 & 321L (4)
- CHEM 331 & 331L (4), 411 & 411L (4)
- EARTH 353 (3), 370 (3)
- Electives to complete 135 credit hours

Environmental Science Courses:

ENVS 412, 412D, Introduction to Geographic Information Systems, 3 cr, 2 cl hrs, 3 lab hrs

Offered Spring semester on demand

An introduction to the concepts of geographic information systems (GIS). Theoretical background to GIS; introduction to the nature and analysis of spatial data. ArcView and/or ArcGIS. Shares lecture with GEOL 512, with additional expectations for graduate credit. Same as EARTH 412.

ENVS 438, Advanced Geographic Information Systems, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Consent of instructor

Advanced topics in geographic information systems (GIS) with a focus on applications in environmental sciences. Emphasis on theoretical aspects and practical applications of GIS science and technology and its integration with remote sensing data and field measurements. Computing exercises and programming projects utilizing GIS software. Discussion of GIS integration with environmental modeling. Shares lecture with GEOL/HYD 538, with additional expectations for graduate credit.

ENVS 472, Senior Seminar, 1 cr, 1 cl hrs

Offered in spring semester

Undergraduate students in Environmental Science are required to give one seminar on research resulting from the paper written for 491 or 492.

Fine Arts

The fine arts program provides an opportunity for students to work in drawing, sculpture, painting, and other endeavors employing creative imagination. Although it is a nonmajor program, fine arts is significant as an area of study, offering elective possibilities in other curricula.

All fine arts offerings are dependent upon student interest and the availability of instructors.

For a complete listing of current Fine Arts offerings, visit <http://ced.nmt.edu> or call (575) 835.6581.

Fine Arts Courses:

The following sampling of Fine Arts courses are graded S/U and may be used for elective credit only. Classes may be taken multiple times for credit.

F A 130C Intro to New Mexico Tin Punching

1 cr, 2 cl hrs

Fundamental tools and processes in creating traditional Hispanic folk art.

F A 140C Introduction to Digital Photography

1 cr, 2 cl hrs

A basic foundation in the use of digital SLR (Single Lens Reflex) or high-end digital point-and-shoot cameras. The first half of the course covers the technical aspects of photography, the camera and its functions. The second half of the course covers composition and the more aesthetic nature of photography and allows students to find their "eye" in photography.

F A 145C Introduction to Photoshop

1 cr, 2 cl hrs

A basic foundation in Photoshop, the premier image manipulation application from Adobe. At the end of the course, the student will be able to open an image with Photoshop, make non-destructive changes to the image, and save it as a file optimized for either print or web/email output. Advanced techniques, such as combining multiple images using layer masks and layer blending modes to create a new, unique image, will be explored.

F A 150C Drawing and Painting 1 cr, 2 cl hrs

Survey of introductory skills and techniques using a variety of drawing and painting media

F A 151C Technical and Industrial Drawing 1 cr, 2 cl hrs

Free hand three dimensional and industrial drawing techniques

F A 152C Painting in Oils 1 cr, 2 cl hrs

Geared toward a relaxing approach to the introduction of the fine art of oil painting, the purpose of this course is to provide background for your future oil painting experiences and serve as an outlet to relax.

F A 153C Painting in Acrylics 1 cr, 2 cl hrs

Basic methods and skills in acrylic painting

F A 160C Stained Glass and Mosaics 1 cr, 2 cl hrs

Introduction to materials and construction techniques of stained glass panels and mosaic objects

F A 240C Photography 1 cr, 3 cl hrs

Technical and aesthetics process in Photography as an art form

F A 260C Stained Glass I 1 cr, 3 cl hrs

Investigation of tools and techniques in creating inspired stained glass compositions.

F A 261C Glass Fusing/Slumping 1 cr, 3 cl hrs

Fundamental tools and processes in creation of glass objects; mold making and slumping processes used in basic kiln forming.

F A 262C Glass Bead Making 1 cr, 3 cl hrs

Exploration of flame working methods and techniques used in creating wearable art

F A 263C Stained Glass II 1 cr, 3 cl hrs

Prerequisite: FA 260C or consent of instructor

Students will investigate more complex designs, tools and equipment in stained glass, including three dimensional and sculptural designs.

F A 264C Stained Glass Design 1 cr, 3 cl hrs

Prerequisite: FA 260C or consent of instructor

Students will learn to design stained glass, and will explore design elements, pattern making, and pattern alignment.

F A 265C Stained Glass Interpretation 1 cr, 3 cl hrs

Prerequisite: FA 260C or consent of instructor

Students will study art masterpieces in other media and recreate them in stained glass.

F A 270C Hand Building in Clay 1 cr, 3 cl hrs

Studio arts survey of hand forming techniques used in creating diverse utilitarian and sculptural ceramics. Accommodates all skill levels

F A 271C Wheel Thrown Ceramics I 1 cr, 3 cl hrs

Prerequisite: FA 270C, Hand Building in Clay

Technical and aesthetic processes used in functional wheel thrown ceramics. Accommodates all skill levels

F A 272C Sculptural Ceramics 1 cr, 3 cl hrs

Studio art class in three dimensional construction of abstract and figurative sculpture. Accommodates all skill levels

F A 273C Wheel Thrown Ceramics II 1 cr, 3 cl hrs

Prerequisite: FA 270C, Hand Building in Clay

Students will learn and practice advanced wheel and decorative techniques.

F A 280C Beginning Enameling 1 cr, 3 cl hrs

The art of fusing glass to metal, safe handling of equipment and chemicals in beginning techniques

F A 281C Enameling II 1 cr, 3 cl hrs

Prerequisite: FA 280C, Beginning Enameling

The art of fusing glass to metal using advanced techniques and methods

F A 282C Beginning Metal Arts/Lapidary 1 cr, 3 cl hrs

Fabrication techniques in metal construction: cutting, shaping and soldering, lost wax casting. Lapidary works of cut stone may be incorporated into metal processes.

F A 283C Metal Arts/Lapidary II 1 cr, 3 cl hrs

Prerequisite: FA 282C, Beginning Metal Arts/Lapidary

Continued development of skills and processes in lapidary and metal work

F A 284C Precious Metal Clay 1 cr, 3 cl hrs

Prerequisites: FA 283C and consent of instructor

The art of kiln fired fused copper, bronze and silver metals in creating wearable art. Safe handling of kilns and equipment

F A 285C Precious Metal Clay II 1 cr, 3 cl hrs

Prerequisite: FA 284C and consent of instructor

Continued exploration of skills and techniques acquired in PMC I

F A 286C Armor Making 1 cr, 3 cl hrs

Prerequisite: FA 282C, Beginning Metal Arts/Lapidary

Hot and cold working of steel and leather in historical design and construction of wearable medieval protective clothing.

Health & Wellness

Health and wellness courses provide students with the opportunity to take part in a variety of health and wellness activities. Classes entail basic skill instruction, and participation is required for credit.

HW classes are generally offered for one credit and are dependent upon student interest and the availability of instructors.

For a complete listing of current Health and Wellness offerings, visit <http://ced.nmt.edu> or call (575) 835.6581.

The following HW courses are graded S/U and may be used for elective credit only. Classes may be taken multiple times for credit.

HW 120C Beginning Yoga 1 cr, 2 cl hrs

Introductory practices focus on alignment, strength, breath relaxation, and restoration

HW 121C Gentle Yoga 1 cr, 2 cl hrs

Focus on stress reduction, body/breath awareness and flexibility

HW 122C Slow Flow Yoga 1 cr, 2 cl hrs

Instruction supports structural integrity of spine, back and abdominals

HW 123C Pilates Matwork 1 cr, 2 cl hrs

Designed exercise program involves the entire body while focusing on strengthening the core muscles of the torso. Exercises promote coordination, balance and strength

HW 220C Intermediate Yoga 1 cr, 2 cl hrs

Prerequisite: PR 120C or consent of instructor.

Intermediate training and skill techniques in Yoga

Information Technology

Professors Liebrock, Soliman, Sueyoshi, Wedeward
Associate Professors Anselmo (Program Coordinator),
Mazumdar, Shin (Chair of the Department), Zheng
Assistant Professor Rezgui

Degree Offered: B.S. in Information Technology

Information Technology (IT) is an evolving interdisciplinary subject that has been driven and shaped by the rapid development of computing, communication, and Internet-related technologies and their tremendous impact on our daily lives. In contrast to the more traditional Information Systems discipline, Information Technology deals with the development, utilization, interrelation, and confluence of computers, networking, telecommunication, business, and technology management in the context of the global Internet. As we enter the Information Age of the 21st century, society will be increasingly dependent on Information Technology and demand for IT professionals will remain high throughout the decades to come.

The *Bachelor of Science in Information Technology* program at New Mexico Tech is administered jointly by the *Computer Science & Engineering* and *Management* departments. The curriculum includes relevant computer science, management, and engineering courses and emphasizes secure information systems and information assurance that are among the areas of research at Tech's Institute for Complex Additive Systems Analysis (ICASA) where IT students may find employment or internship opportunities. Students must also take a sequence of 12 hours of technical electives to broaden or deepen their knowledge in an IT area of their interest. Graduates of the IT program will be well prepared for immediate industry employment or graduate study in an IT-related discipline.

Undergraduate Program

Bachelor of Science in Information Technology

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- CSE 222 (3), 241 (3)
- IT 101 (2), IT 113 (4), 122 (3), 213 (3), 221 (3), 263 (3), 311 (3), 321 (3), 326 (3), 353 (3), 373 (3), 382 (3), 481 (3), 482 (3)
- MATH 283 (3)
- PSY 121 (3) (can be applied as a social science course in the general education core curriculum)

- Technical Electives: a sequence of 12 hours of computer science, information technology, or management courses numbered 300 or higher, *pre-approved* by the student's advisor and an IT Program Coordinator, with no more than one course numbered IT 485. Students are encouraged to select a coherent set of courses as technical electives that will prepare them for a specific focus in their career.
- Each of the above courses must be completed with a grade of C or better.
- General Electives to complete 130 credit hours.

Sample Curriculum for the Bachelor of Science Degree in Information Technology

Semester 1

- 4 MATH 131 (calculus)
- 1 IT 101 (intro to comp sci & information tech)
- 4 IT 113 (intro to programming)
- 3 ENGL 111 (college English)
- 13 Total credit hours

Semester 2

- 4 MATH 132 (calculus)
- 3 IT 122 (algorithms and data structures)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 112 (college English)
- 14 Total credit hours

Semester 2.5 (Summer)

- 4 Chem 122 & 122L (general chemistry II)
- 4 Total credit hours

Semester 3

- 3 IT 221 (computer and network organization)
- 3 IT 263 (information protection and security)
- 3 CSE 241 (foundations for computer science)
- 5 PHYS 121 & 121L (general)
- 3 PSY 121 (general psychology)
- 17 Total credit hours

Semester 4

- 3 CSE 222 (systems programming)
- 3 IT 351 (complex system modeling and simulation)
- 3 IT 213 (intro to object oriented programming)
- 3 MATH 283 (introduction to applied statistics)
- 5 PHYS 122 & 122L (general)
- 17 Total credit hours

Semester 5

- 3 IT 321 (internet and web programming)
- 3 IT 311 (human info processing and decision making)
- 3 IT 373 (intro to database design and management)
- 3 ENGL 341 (technical writing)
- 3 Social Science
- 1 Elective
- 16 Total credit hours

Semester 6

- 3 IT 326 (software engineering)
- 3 IT 382 (legal and ethical info technology issues)
- 4 Biology/Earth Science/Engineering with lab
- 6 Electives
- 16 Total credit hours

Semester 7

- 6 Technical Electives
- 3 IT 481 (senior secure system design project)
- 3 Social Science
- 3 Humanities
- 3 Electives
- 18 Total credit hours

Semester 8

- 6 Technical Electives
- 3 IT 482 (senior secure system design project)
- 3 Humanities/Social Science
- 3 Electives
- 15 Total credit hours

Information Technology Courses:

In the following, each prerequisite requires a grade of C or better.

IT 101, Introduction to Computer Science & Information Technology, 2 cr, 2 cl hrs

Brief overview of the discipline of computer science and information technology topics including computer architecture, operating systems and networks, automata and models of computation, programming languages and compilers, data structures, algorithms, databases, security and information assurance, artificial intelligence, graphics, and social/ethical issues of computing. (Same as CSE 101.)

IT 107, Introduction to Computer Programming using Python, 4 cr, 3 cl hrs, 2 lab hrs

Co-requisite: Math 103

The course is designed to introduce programming and its applications to scientists and engineers. The first part of the class focuses on problem solving, algorithm development, top-down design, modular programming, debugging, testing, data types, flow-control, looping, iteration and recursion, fundamental data structures, and an introduction to object oriented programming. The second part of the class explores data analysis with Python. (Same as CSE 107.)

IT 113, Introduction to Programming, 4 cr, 3 cl hrs, 3 lab hrs

Co-requisite: MATH 131

The course is designed to introduce problem solving and programming in C to Computer Science majors and those interested in applications of the language that involve dynamic structures and memory management. Topics include algorithm development; top-down design; modular programming; debugging; testing; control structures including selection, iteration and recursion; number systems; data representation; data types including arrays, strings, pointers and dynamic structures involving memory management. Concepts implemented through extensive programming using good programming style. (Same as CSE 113)

IT 122, Algorithms and Data Structures, 3 cr, 3 cl hrs

Prerequisite: IT 113 with a grade of C or higher

Corequisite: Math 132

Fundamental data structures including linked lists, trees, hash tables, and graphs. Algorithms for sorting, searching, and other fundamental operations. Introduction to mathematical foundations for analysis of iterative and recursive algorithms and for basic correctness proofs. Analysis of algorithms. Implementation of selected algorithms using sound programming methodologies. (Same as CSE 122.)

IT 213, Introduction to Object Oriented Programming, 3 cr, 3 cl hrs

Prerequisite: IT 101, 113, 122 each with a grade of C or higher

Introduction to programming in an object oriented language (e.g., Java): review of problem solving, algorithm development, top-down design, modular programming, debugging, testing, control structures including selection, iteration and recursion, data types including arrays, strings, pointers, and dynamic structures. Object oriented concepts will include: objects, classes, inheritance, instances, methods, interfaces, packages, encapsulation, and polymorphism. Concepts implemented through extensive programming using good programming style. (Same as CSE 213.)

IT 221, Computer System Organization, 3 cr, 3 cl hrs

Prerequisite: IT 101, 122 each with a grade of C or higher

The hardware/software interface. Basic organization of computers, operating systems, and computer networks. Memories, buses, interrupts, input and output, and instruction set architecture. Basics of assembly language programming. (Same as CSE 221.)

IT 263, Information Protection and Security, 3 cr, 3 cl hrs

Prerequisite: IT 101, 113 each with a grade of C or higher

Corequisite: IT 221

Concepts of information, message and data. Storage and transmission, retrieval and communications. Authorized users and penetrators. Threats to information confidentiality, integrity, availability, and accountability. Attacks. Degrees of security and costs. Protection mechanisms and security precautions. Authentication and authorization. Encryption. Secure operating systems, communications and networks. Defenses against viruses, worms, and hostile code.

IT 311, 311D, Human Information Processing and Decision Making, 3 cr, 3 cl

Prerequisite: PSY 121 with a grade of C or higher and upper division standing in the IT program

Recent advances in knowledge about how people process and act upon information are presented. Models of human decision making are analyzed in the context of secure information systems and used to assess ways to best manage the people and technology associated with secure information systems.

IT 321, Internet and Web Programming, 3 cr, 3 cl hrs

Prerequisite: IT 213, 221 each with a grade of C or higher

This course has a practical emphasis on the design and techniques for developing internet-based applications, mainly focusing on web programming. Topics include HTML, client-side scripting language (JavaScript), server-side programming (Servlets, JSP, and J2EE), and XML/web services (Java and .NET). This course will also cover some important topics needed for internet-based application developments, such as Internet architectures, basic object-oriented programming (OOP) concepts, and web security. Course work includes substantial programming homework and team-based projects. (Same as CSE 321.)

IT 326, Software Engineering, 3hrs

Prerequisites: IT 122, 213 each with a grade of C or higher

This course provides the introductory overview of software engineering, concentrating on large-scale software system design and implementation. Topics include software life cycle, UML-based design language, design tools and techniques, design documentation, software testing, and software project management. Course work includes a team-based project. (Same as CSE 326.)

IT 328, Secure Software Construction, 3 cr, 2 cl hrs, 1 lab hr

Prerequisite: CSE 222, IT 213 each with a grade of C or higher

Formal methods and practical techniques for the specification, design, implementation, and validation of computer software. Current software engineering and management practices, with emphasis on ensuring software reliability, safety, and security. Course work includes a team project to develop a sizeable, real-world application software. (Same as CSE 328.)

IT 330, Management and Organizational Behavior, 3 cr, 3cl hrs

Prerequisites: ENGL 112 with a grade of C or higher and upper-class standing or consent of instructor

Classical and contemporary organization theories, interpersonal and organization behavior, motivation, communication, leadership, decision process in organizations. (Same as MGT 330.)

IT 351, Modeling and Simulation Technologies for Information Systems, 3 cr, 3cl hrs

Prerequisites: IT 122; CSE 241 each with a grade of C or higher

Fundamentals and techniques for designing and using simulation, modeling, and optimization algorithms with applications in system performance modeling, business infrastructure modeling, and distributed and parallel computing. An introduction to advanced complex systems models. (Same as CSE 351.)

IT 353, Introduction to Computer Networks, 3 cr, 3 cl hrs

Prerequisites: CSE 222 with a grade of C or higher
Usually offered fall semester

Introduction to computer networking, the ISO/OSI protocol stack, LAN, MAN, and WAN. Physical layer: transmission media (wireline and wireless); data signaling, modulation, and coding; multiplexing. Fiber optics networking technology: protocols & examples. Data link Layer: error/flow control — protocols design issues; MAC protocols for channel access and allocation. Wireless technology and protocols standards — IEEE 802.11 physical layer and MAC sublayer protocols. Network layer: subnet switching (CS/DG/VC) & routing protocols (Non/Adaptive); Congestion Control and QoS protocols. ISO vs. (TCP-UDP)/IP the Internet protocol stacks. Internet relays and protocols, e.g., routers, gateways, etc. Introduction to network security. Application layer protocols, E.G., DNS, E-mail, etc. (Same as CSE 353.)

IT 373, Introduction to Database Systems, 3 cr, 3 cl hrs

Prerequisite: IT 122; CSE 241 each with a grade of C or higher

Conceptual modeling and database design using the entity-relationship model. The relational model; relational algebra and relational query languages; design theory for relational databases. Database integrity. Physical data organization. Introduction to problems of concurrency control, recovery, security, and distributed databases. Course work includes a project using SQL and the Oracle Database Management System. (Same as CSE 373.)

IT 382, 382D, Legal, Ethical, & Social Issues of IT, 3 cr, 3 cl hrs

Prerequisite: IT 326 with a grade of C or higher

A survey of current legal IT (and general business and management) issues is presented in this course. Also, social and ethical issues associated with IT and management of secure information systems are surveyed and discussed.

IT 441, Cryptography and Applications, 3 cr, 3 cl hrs

Prerequisites: IT 122; CSE 241 each with a grade of C or higher

This course provides an introductory overview of modern cryptographic theory and techniques, mainly focusing on their application into real systems. Topics include number theory, probability and information theory, computational complexity, symmetric and asymmetric cryptosystems, one-way functions, block and stream ciphers, Kerberos authentication systems, public key infrastructure (PKI), secure socket layer/transport layer security (SSL/TLS), and cryptographic protocols/applications in many real systems. (Same as CSE 441.)

IT 451, 451D, Introduction to Parallel Processing, 3 cr, 3 cl hrs

Prerequisites: CSE 122 or IT 122 with a grade of C or higher

Introduction to supercomputers and massively-parallel machine architecture, models of parallel computation, parallel algorithms, synchronization, parallel languages, data and functional parallelism, parallel performance analysis, popular interfaces, and parallel debugging. Students will gain experience in parallelization of sequential algorithms and implementation of parallel algorithms. (Same as CSE 451.)

IT 453, Advances in Computer Networks and the Internet, 3 cr, 3 cl hrs

Prerequisites: CSE 353 with a grade of C or higher

In depts. Coverage of layering protocols; stacks (ISOOSI and TCP/IP) and computer networks architectures, modern examples of LANs, MANs, WANs protocols/architectures. Recent developments in Fiber optics technology – protocols and architectures. High speed “all-fiber-optics” networks. Internetworking: global addresses/ names and translation, virtual networks and tunnels, routing, subnetworks switching protocols, IPv6, multicasting, Mobile IP. End-to-end protocols, TCP and UDP. Advances in Congestion control and resource allocation. Client-server models & applications. The QoS mechanism integrated/differentiated, ATM QoS. Network security: information and link security, encryption, internetworking security, IPsec, firewalls, VPN, wireless security. Analysis of networks protocols. (Same as CSE 453.)

IT 462, 462D, Systems, Risk and Decision Analysis, 3 cr, 3 cl 3 hrs

Prerequisites: MATH 283 or 382 with a grade of C or higher; upper division standing

Analysis of systems and managerial decisions under conditions of risk or uncertainty. Optimal project evaluations and ranking of alternatives using expected value and expected utility criteria. Topics include risk sharing, Bayesian revision of probabilities, value of information, and preference assessment procedures. (Same as MGT 462.)

IT 463, Information Assurance, 3 cr, 3 cl hrs

Prerequisite: Senior standing

Defense and offensive information warfare. Information system security. Computer break-ins, hacking, and other attack methods. Vulnerability and risk analysis. Theory and applications of cryptography. Intrusion detection and incident response. Security planning and management. (Same as CSE 463.)

IT 466, 466D, Project Management, 3 cr, 3 cl hrs

Prerequisite: MATH 283, MGT 472 each with a grade of C or higher, or consent of instructor

Development of work breakdown structures and multi-factor project simulations to be used in dynamic resource allocations. Assessment and evaluation of project models over time. (Same as MGT 476.)

IT 476, Visualization, 3 cr, 3 cl hrs

Prerequisite: CSE 222 with a grade of C or higher, or consent of instructor

This course presents application of graphical visualization to current problems, with a focus on extracting and representing information in multidimensional data sets using 2D and 3D graphics. Topics include visualization tools and techniques, human vision and perception, color mapping, sound, data representation for insight extraction, time visualization, visual analytics, volume rendering, surface extraction and rendering. Students will develop visualizations of real world problems. (Same as CSE 476.)

IT 481 / IT 482, Senior Secure System Design Project, 3 cr, 3 lab hrs ea

Prerequisite: must have completed all junior-level IT courses each with a grade of C or higher

A substantial system and security-related project taken over 2 regular semesters, under the supervision of a faculty member.

IT 485, Undergraduate seminar on Special Topics 3 cr, 3 cl hrs

Prerequisite: Senior standing, one semester of upper division courses in computer science/information technology, and consent of the instructor

A research seminar for undergraduate students with a focus either on special topics in computer science/information technology or on the methodology and skills required for research in computer science/information technology. *Use as a technical elective is limited (see requirements above), but may be taken multiple times as a general elective.*

Faculty Research Interests

Anselmo—Agent-Based Financial System Modeling and Simulation, Non-Financial Risk Modeling and Analysis

Liebrock—Computer Forensics, Information Assurance, Parallel Processing, Well Posedness Analysis, Visualization

Mazumdar—Mobile and distributed databases: Integrity, Privacy, Security; Information Systems, Software Integrity

Rezgui —Cloud Computing, Service-based computing, Energy-aware cellular networks

Shin— System security, Usable Security, Applied Cryptography, Software Engineering

Soliman—Computer Networks — fiber/wireless modern technologies and protocols, Sensor Networks — modern technologies and protocols, Computer/Sensor Networks Security, Programming Languages, Neural Networks — applications in image compression, cloud computing management, and sensor networks

Sueyoshi—Management Science, Data Envelopment Analysis, Risk and Policy Analysis

Wedeward—Adaptive Control, Robotic Systems

Zheng—Mobile Computing, Computer and Network Security, Machine Learning and its Applications

Management

Professor Sueyoshi

Associate Professor Anselmo, Ostergren

Assistant Professors Reinow (Chair of the Department), Yuan

Adjunct Faculty: Foster, Mazumdar, Peterson

Degrees offered: A.S. in Business; B.S. in Management and B.S. in Management of Technology

The Department of Management provides undergraduate degree programs that draw heavily on Tech's strengths in science, engineering, and technology. The aim of the department is to develop in students substantive decision-making skills and tools, as well as the functional knowledge required to effectively manage complex technology-based organizations in today's competitive global economy. Management students take the same basic science and math courses required of every Tech student—two semesters each of chemistry, physics, calculus, and another lab science such as biology, engineering, or geology. Added to this foundation are courses in accounting, business computer systems, economics, finance, management, marketing, operations research, and statistics.

New Mexico Tech offers degrees in management and management of technology. The B.S. in Management is appropriate for those planning to enter the fields of human resources management, labor relations, or general management. The B.S. in Management of Technology integrates management course work with study in an engineering field of the student's choice. This degree focuses on the application of quantitative methods to problem solving in management. In accordance with the overall mission of New Mexico Tech, it is expected that problems addressed will be primarily within engineering and applied science disciplines, including natural resource and environmental management problems. Each management student is assigned a faculty advisor who will help him or her select a degree option and recommend courses to be taken.

The Department of Management also offers an Associate of Science degree in Business. This program is designed for students seeking to complete a two-year degree in business, and/or those who may wish to transfer to a four-year bachelor's program in business or management. Required courses are transferable among participating New Mexico institutions.

Undergraduate Program

Associate of Science in Business

Minimum credit hours required—65

The following courses are required:

- ACCT 201 (3), 202 (3), 371 (3)
- ECON 251 (3), 252 (3)
- ENGL 111 (3), 112 (3)
- MGT 330 (3)
- Mathematics: Six credit hours chosen from MATH 103 (3), 104 (3), 105 (5), 131 (4)
- TC 151 (3)
- Business Electives: Nine credit hours selected in consultation with the faculty advisor
- Humanities and Social Science Elective: Three credit hours chosen from Area 4 or Area 5 of the General Education Core Curriculum (page 7)
- A total of eight credit hours in courses with associated laboratories from the disciplines of biology, chemistry, earth science, or physics
- Electives to complete 65 credit hours
Students must achieve a minimum GPA of 2.0 in required courses in order to graduate.

Sample Curriculum for the Associate of Science in Business

Summer

5 Mathematics
5 Total credit hours

Semester 1

3 ENGL 111 (college English)
3 Mathematics
3 ACCT 201 (fundamentals I)
3 ECON 251 (macroeconomics)
12 Total credit hours

Semester 2

3 ENGL 112 (college English)
4 Science with lab (biol, chem, earth science, or physics)
3 ACCT 202 (fundamentals II)
3 ECON 252 (microeconomics)
13 Total credit hours

Semester 3

3 BA 315 (business law I)
3 ACCT 371 (financial accounting)
4 Science with lab (biol, chem, earth science, or physics)
3 TC 151 (intro to visual communication)
3 Humanities/Social Science
16 Total credit hours

Semester 4

3 BA 317 (business law II)
9 Business Electives
4 Electives
16 Total credit hours

Core Requirements for the Bachelor of Science in Management

In addition to the General Education Core Curriculum (page 7), the following core of business and economics courses is required of all Management students:

- ACCT 201 (3), 202 (3); ACCT 350 is recommended
- BCS 283 (3)
- CSE 113 (4) or ES 111 (3)
- MGT 101 (1), 302 (3), 330 (3) 335(3), 462 (3), 472 (3), 476 (3), 481 (3), 486 (3)
- ECON 251 (3), 252 (3). *These courses may be used to fulfill the Area 4 of the General Education Core Curriculum, page 7.*
- At least two semesters of a single approved foreign language are strongly suggested but not required.
- Electives to complete 130 credit hours. To be selected in consultation with a faculty advisor.

Any required class or technical elective used toward a B.S. in Management or a B.S. in Management of Technology may not be taken on an S/U basis. Management majors must achieve a minimum GPA of 2.0 in required courses in order to graduate.

Bachelor of Science in Management

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7) and the core business requirements (above), the following courses are required:

- Management Elective Sequence: At least nine (9) credit hours selected in consultation with and approved by the student's faculty advisor.
- ACCT 350 (3) is recommended

Sample Curriculum for the Bachelor of Science in Management

Semester 1

- 1 MGT 101 (modern management issues)
- 3 ENGL 111 (college English)
- 4 CHEM 121 & 121L (general)
- 4 MATH 131 (calculus)
- 4 CSE 113 or ES 111

16 Total credit hours

Semester 2

- 3 ENGL 112 (college English)
- 4 CHEM 122 & 122L (general)
- 4 MATH 132 (calculus)
- 4 Biology/Earth Science/Engineering with lab

15 Total credit hours

Semester 3

- 5 PHYS 121 & 121L (general)
- 3 ACCT 201 (fundamentals 1)
- 3 ECON 251 (macroeconomics)
- 3 Elective
- 3 Social Science

17 Total credit hours

Semester 4

- 5 PHYS 122 & 122L (general)
- 3 ACCT 202 (fundamentals II)
- 3 BCS 283 (applied statistics)
- 3 ECON 252 (microeconomics)
- 3 Humanities/Social Science

17 Total credit hours

Semester 5

- 3 ACCT 350 (managerial accounting)
- 3 BA 315 (business law I)
- 3 MGT 330 (organizational behavior)
- 3 MKT 335 (principles)
- 3 Management Elective

18 Total credits

Semester 6

- 3 FIN 302 (principles)
- 3 MGT 462 (decision analysis)
- 3 ENGL 341 (technical writing)
- 3 Management Elective
- 6 Electives

18 Total credit hours

Semester 7

- 3 MGT 451 (leadership & motivation)
- 3 MGT 472 (production & operations)
- 3 Humanities
- 3 Management Elective
- 3 Elective

15 Total credit hours

Semester 8

- 3 BA 490 (business policy)
- 3 MGT 473 (production and operations II)
- 3 MGT 481 (senior seminar)
- 3 Humanities
- 3 Management Elective

15 Total credit hours

Bachelor of Science in Management of Technology

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7) and the core business requirements (page 86), the following courses are required:

- ES 201 (3), 216 (3), and nine (9) approved credit hours of engineering courses numbered 300 or above
- ES 316 does not count toward the Management of Technology degree
- MATH 231 (4)
- At least two semesters of a single approved foreign language are strongly suggested but not required.
- Electives to complete 130 hours

Sample Curriculum for the Bachelor of Science in Management of Technology

Semester 1

- 1 MGT 101 (modern management issues)
- 3 ACCT 201 (fundamentals I)
- 3 ENGL 111 (college English)
- 4 CHEM 121 & 121L (general)
- 4 MATH 131 (calculus)
- 12 Total credit hours

Semester 2

- 3 ACCT 202 (fundamentals II)
- 3 ENGL 112 (college English)
- 4 CHEM 122 & 122L (general)
- 4 MATH 132 (calculus)
- 3 ES 111 or CSE 113 (4 cr)
- 17 or 18 Total credit hours

Semester 3

- 5 PHYS 121 & 121L (general)
- 3 ECON 251 (macroeconomics)
- 4 MATH 231 (calculus)
- 3 ES 201 (statics)
- 16 Total credit hours

Semester 4

- 5 PHYS 122 & 122L (general)
- 3 BCS 283 (applied statistics)
- 3 ECON 252 (microeconomics)
- 3 ES 216 (fluid mechanics)
- 4 Biology/Earth Science/Engineering with lab
- 18 Total credit hours

Semester 5

- 3 ACCT 350 (managerial accounting)
- 3 BA 315 (business law I)
- 3 MGT 330 (organizational behavior)
- 3 MKT 335 (principles)
- 3 Engineering prerequisite or elective
- 15 Total credit hours

Semester 6

- 3 FIN 302 (principles)
- 3 ENGL 341 (technical writing)
- 3 Humanities
- 3 Social Science
- 6 Engineering prerequisite or Elective
- 18 Total credit hours

Semester 7

- 3 MGT 462 (decision analysis)
- 3 MGT 472 (production & operations I)
- 3 Humanities
- 6 Engineering prerequisite or Elective
- 15 Total credit hours

Semester 8

- 3 BA 490 (business policy)
- 3 MGT 481 (senior seminar)
- 3 Engineering Elective
- 3 Humanities/Social Science
- 3 Management or Engineering Elective
- 15 Total credit hours

Minor in Management

Minimum credit hours required—18

The following courses are required:

- MGT 302 (3), 330 (3), 335 (3) 472 (3)
- Six (6) credit hours of Management Department courses numbered 300 or above.

Note: ECON 252 and BCS/MATH 283 are prerequisites for MGT 302 and MGT 335. Non-majors must obtain instructor consent in lieu of the ACCT 202 prerequisite for MGT 302.

Accounting Courses:

ACCT 201, 201D, Fundamentals of Accounting I, 3 cr, 3 cl hrs

Financial accounting procedures, concepts, and reports for sole proprietorships.

ACCT 202, Fundamentals of Accounting II, 3 cr, 3 cl hrs

Prerequisite: ACCT 201

Financial accounting for partnerships and corporations, an introduction to managerial accounting concepts.

ACCT 350, 350D, Managerial Accounting, 3 cr, 3 cl hrs

Prerequisite: ACCT 202 or consent of instructor

Cost-benefit choices among accounting methods and systems in support of strategic decisions and operational control, including behavioral effects of accounting systems within organizations. Analysis of cost behavior patterns and how they alter cost accounting for automated manufacturing environments. Construction of budgets, forecasts, and estimates for new product/process costs.

ACCT 353, 353D, Cost Accounting, 3 cr, 3 cl hrs

Prerequisite: ACCT 202 or consent of instructor

The development and use of cost accounting for inventory valuation, income determination, cost control including process accounting and variance analysis.

ACCT 371, Financial Accounting I, 3 cr, 3 cl hrs

Prerequisite: ACCT 202

A detailed study of the financial recording and reporting process. Emphasis is placed on the form and content of financial statements.

ACCT 372, Financial Accounting II, 3 cr, 3 cl hrs

Prerequisite: ACCT 371

Current financial accounting theory and practice as they relate to financial statement preparation and analysis. Emphasis on special topics includes accounting for pensions and leases, accounting changes, and earnings per share presentation. Topics of current financial accounting interest are reviewed as they develop.

ACCT 403, Tax Accounting, 3 cr, 3 cl hrs

Prerequisite: ACCT 372 or consent of instructor

Federal income tax laws and the determination of taxable income for individuals, partnerships, corporations, and fiduciaries. Tax research and planning.

ACCT 405, Accounting for Non-Profit Organizations, 3 cr, 3 cl hrs

Prerequisite: ACCT 372 or consent of instructor

Control and reporting problems for government organizations and other non-profit entities. Fund accounting principles, procedures, and reports.

ACCT 490, Selected Topics, 1–3 cr, 1–3 cl hrs

Prerequisite: ACCT 202; FIN 302; ECON 251, 252; MGT 330; BCS 283; MKT 335; senior standing

Current topics in accounting.

ACCT 491, Directed Study, 1–3 cr, 1–3 cl hrs

Prerequisite: upper-class standing or consent of instructor

Individual studies directed by consenting faculty with prior approval of the department head.

Business Computer Systems Courses:**BCS 254, Introduction to Applied Linear Algebra, 3 cr, 3 cl hrs, 1.5 lab hrs**

Prerequisite: MATH 131 passed with grade C- or better

Solution of linear systems. Matrix algebra. Rank. Determinants. Eigenvalues and eigenvectors. Numerical aspects of matrix calculation. Introduction to vector spaces and linear transformations. Applications. (Same as MATH 254)

BCS 283, Elementary Applied Statistics, 3 cr, 3 cl hrs, 1.5 lab hrs

Prerequisite: MATH 132 passed with grade C- or better

Exploratory data analysis. Introduction to probability and random variables. Concepts of population and sample. Estimation and hypothesis testing. Simple linear regression and one-way analysis of variance. Techniques in data analysis using statistical computer packages. (Same as MATH 283)

BCS 415, Introduction to Operations Research: Deterministic Methods, 3 cr, 3 cl hrs

Prerequisite: BCS 254 passed with grade C- or better

A survey of operations research techniques including linear programming, non-linear models, and graph theoretical models. (Same as MATH 415)

BCS 486, Introduction to Stochastic Processes, 3 cr, 3 cl hrs

Prerequisites: MATH 254 and 382, each passed with grade C- or better

Conditioning. The Poisson process. Theory of Markov chains, continuous time Markov and semi-Markov processes. Topics from renewal theory and Markov renewal theory. Queuing Theory. Applications in science and engineering. (Same as MATH 486)

BCS 488, Introduction to Operations Research: Stochastic Methods, 3 cr, 3 cl hrs

Prerequisites: Math 382, passed with grade C- or better

Monte Carlo Simulation Theory. Application of simulation to problems in science, engineering, and business. Queuing systems simulation. Inventory theory. (Same as MATH 488)

BCS 491, Directed Study, 1–3 cr, 1–3 cl hrs

Prerequisite: upper-class standing or consent of instructor

Economics Courses:

These courses may be used to Area 4: Social Sciences of the General Education Core Curriculum, page 7.

ECON 251, Principles of Macroeconomics, 3 cr, 3 cl hrs

Macroeconomic theory and policy analysis. Economic aggregates; fiscal and monetary policy; productivity and economic growth; banking system; national debt. Policy innovation: crisis and response; Keynesian, monetarist and supply-side models. Free trade, protectionist and mercantilist strategies. Exchange rate systems and macroeconomic management. [NMCCNS ECON 2113: General Education Area IV]

ECON 252, Principles of Microeconomics, 3 cr, 3 cl hrs

Microeconomic theory and applications. Market allocation of resources; supply and demand; theory of marginal analysis; market types; market failure; regulation and antitrust; economic growth and innovation; business finance; economic globalization; and cultures of capitalism. [NMCCNS ECON 2123: General Education Area IV]

ECON 362, Managerial Economics, 3 cr, 3 cl hrs

Prerequisites: ECON 251, 252

A coordination of economic theory and managerial practice. Consumer demand, production functions, cost behavior, output determination, and pricing within various market structures.

ECON 372, Natural Resource and Environmental Economics, 3 cr, 3 cl hrs

Prerequisites: ECON 362 or ES 316 or consent of instructor

Introduction to the economic concepts and methods used in defining and analyzing natural resources and environmental quality problems.

ECON 490, Selected Topics, 1–3 cr, 1–3 cl hrs

Prerequisite: Upper-class standing or consent of instructor
Current topics in economics.

ECON 491, Directed Study, 1–3 cr, 1–3 cl hrs

Prerequisite: Upper-class standing or consent of instructor

Finance Courses**FIN 410, Theory of Financial Decisions, 3 cr, 3 cl hrs**

Prerequisites: FIN 302; BCS 283; or consent of instructor

Detailed study of contemporary capital market and market equilibrium theories. Consideration of individual and firm risk attitudes and ways of dealing with financial risk. Discussion of firm valuation methods and firm level approaches to risky financial decision making.

FIN 480, Investments, 3 cr, 3 cl hrs

Prerequisites: BCS 283; FIN 302 or ES 316; or consent of instructor

Portfolio theory and empirical capital market analysis. Contemporary investment theory, including option pricing models and derivatives. Active portfolio management in light of the vast array of financial investment alternatives available in today's markets.

FIN 490, Selected Topics, 1–3 cr, 1–3 cl hrs

Prerequisite: Upper-class standing or consent of instructor
Current topics in finance.

FIN 491, Directed Study, 1–3 cr, 1–3 cl hrs

Prerequisite: Upper-class standing or consent of instructor

Management Courses:**MGT 101, Modern Management Issues, 1 cr, 1 cl hr**

Seminar on modern management issues and the role of managerial personnel in today's technology firms. Guest speakers and faculty presenting overview of current issues and research topics.

MGT 301, Survey of Engineering Management, 3 cr, 3 cl hrs

Prerequisites: ES 110 and 111 or equivalent

Survey designed for engineering majors. Topics include introductions to qualitative and quantitative management models and their implementation.

MGT 302, Introduction to Financial Economics 3 cr, 3 cl hrs

Prerequisites: ACCT 202, BCS 283, ECON 252, or consent of instructor

Introduction to cost analyses, financial management and planning, introduction to financial investments including debt, and capital budgeting models with examples of applications.

MGT 330, Management and Organizational Behavior, 3 cr, 3 cl hrs

Prerequisites: ENGL 112 and upper-class standing or consent of instructor

Classical and contemporary organization theories, interpersonal and organization behavior, motivation, communication, leadership, decision process in organizations.

MGT 331, Human Resource Management, 3 cr, 3 cl hrs

Planning and utilization of human resources, including recruitment, selection, equal employment opportunity, safety, compensation, appraisal, unions, training, and job evaluation.

MGT 335, 335D, Marketing of New Products and Innovations, 3 cr, 3 cl hrs

Prerequisites: ECON 252; BCS 283; or upper-class standing and consent of instructor

Application of marketing theory and practice to developing new products and innovations. Focus on marketing early stage technology innovations and products from concept to implementation.

MGT 381, Strategic Market Analysis, 3 cr, 3 cl hrs

Prerequisites: BCS 283; FIN 302; MKT 335; upper-class standing

Analysis of data derived from either survey instruments, archival sources, or both. Design and implementation of instruments designed to elicit information useful to managers. Single and multiple variable impacts on managerial decision making.

MGT 451, Technology Management Seminar, 3 cr, 3 cl hrs

Prerequisite: MGT 330

Seminar focused on current management issues in complex technology organizations. Motivating and measuring performance in ambiguous situations. Leadership and growth issues in entrepreneurial technology organizations.

MGT 462, 462D, Systems, Risk, and Decision Analysis, 3 cr, 3 cl hrs

Prerequisites: BCS 283 or MATH 283 or MATH 382 and upper-class standing or consent of instructor. Management majors should enroll in BCS 283.

Analysis of systems and managerial decisions under conditions of risk or uncertainty. Optimal project evaluations and ranking of alternatives using expected value and expected utility criteria. Topics include risk sharing, Bayesian revision of probabilities, value of information, and preference assessment procedures. (Same as IT 462)

MGT 472, Production and Operations Management I, 3 cr, 3 cl hrs

Prerequisites: BCS 283 and upper-class standing or consent of instructor

Application of quantitative methods to problems encountered in management. Problem solving emphasis with extensive use of applications software. Topics include linear and integer programming, forecasting, queueing theory and simulation.

MGT 473, Production and Operations Management II, 3 cr, 3 cl hrs

Prerequisites: MGT 472 and upper-class standing or consent of instructor

Application of concepts and principles related to management of the production function in manufacturing and services. Problem solving emphasis with extensive use of applications software. Topics include independent and dependent demand inventory models, facility layout, facility location; quality control; and project management.

MGT 476, 476D, Project Management, 3 cr, 3 cl hrs

Prerequisites: MATH 283, MGT 472 or consent of instructor

Development of work breakdown structures and multi-factor project simulations to be used in dynamic resource allocations. Assessment and evaluation of project models over time.

MGT 481, Senior Seminar, Technical Management, 3 cr, 3 cl hrs

Prerequisite: upper-class standing and consent of instructor

MGT 488, Technology Entrepreneur Workshop, 3 cr, 3 cl hrs

Prerequisites: FIN 302; MGT 381; ACCT 202; senior standing; or consent of instructor

This workshop is designed to familiarize participants with the process of technology marketing. Assessment of new-product marketability, development of marketing and business plans, presentation of plans in a competitive environment to an evaluation panel composed of people from various business backgrounds.

MGT 486, Business Policy/Corporate Strategy, 3 cr, 3 cl hrs

Prerequisites: ACCT 202; FIN 302; ECON 251, 252; MGT 330; BCS 283; MKT 335; senior standing

Integration of the basic functions of a business enterprise—e.g., marketing, finance, and production—through case analysis. From the perspective of top management, emphasis will be placed on examination of external environments, and the development of strategies for the organization's creation of proper relationships and responses to social, political, and economic conditions.

MGT 490, 490D, Selected Topics, 1–3 cr, 1–3 cl hrs

Prerequisite: Upper-class standing or consent of instructor
Current topics in management.

Faculty Research Interests

Anselmo—Decision Analysis and Risk Management,

Computational Finance, Electronic Commerce

Mazumdar—Database Systems, Massive Storage

Systems, Computational Logic

Ostergren—Program Management, Product

Development, Total Quality Management

Peterson—Management, Economics, Accounting

Sueyoshi—Management Science, Data Envelopment

Analysis, Risk and Policy Analysis

Mathematics

Professors Avramidi (Chair of the Department), Borchers, Hossain, Stone (Dean of Arts & Sciences), Wang
Associate Professors Aitbayev, Kerr, Makhnin, Starrett
Assistant Professor Zhang
Instructors Ballou, Bukowski
Emeritus Faculty: Arterburn, Schaffer, Sharples

Degrees Offered: B.S. in Mathematics, M.S. in Mathematics with specialization in Operations Research and Statistics, M.S. in Mathematics with specialization in Analysis, M.S. in Mathematics with specialization in Industrial Mathematics; Ph.D. in Applied and Industrial Mathematics

Students and faculty in the mathematics department at Tech are involved in many areas of mathematics, from pure mathematics to applied mathematics, operations research, and statistics. The department offers bachelors, masters, and Ph.D. degrees in mathematics, and plays an important role in teaching mathematics to students in other disciplines. Faculty and students are also involved in a number of research projects, many of them in conjunction with researchers in other departments at Tech and at other institutions.

There are career opportunities for mathematics students at both the bachelor's and master's levels. Students in mathematics can prepare for actuarial careers, careers in education, and careers in a number of industries, including telecommunications, aerospace, and computer. Preparation for a career in industry should include a broad background in mathematics, modeling skills, computer skills, expertise in an area outside mathematics, and communication skills. Degree requirements are designed to help students develop these important abilities.

Mathematics can also be studied in preparation for more advanced work in a variety of fields including pure mathematics, applied mathematics, operations research, statistics, scientific computing, and business administration. Many students choose to combine a major in mathematics with a major in a second field such as management, computer science, engineering, or physics. A strong background in mathematics can be very helpful in graduate studies.

Students in the mathematics department at both the undergraduate and graduate level have many opportunities to interact with faculty and participate in a variety of mathematical activities. The department has weekly seminars in which faculty, graduate students, and visitors present their research. Both undergraduates and graduates are involved in research projects. Many students are employed by the department as graders, lab facilitators, teaching assistants, and research assistants. Undergraduate students regularly compete in the William Lowell Putnam mathematics competition and in the COMAP contest in mathematical modeling.

Undergraduate Program

Bachelor of Science in Mathematics

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- *Introduction to Computer Science*: CSE 113 (4) or ES 111 (3)
- *Basic Mathematics*: MATH 231 (4), 254 (3), 335 (3), 336 (3), 352 (3), 372 (3), 382 & 382L (4), 454 (3)
- *Mathematical Modeling*: MATH 430 (3)
- *Mathematics Electives*: Four courses from at least two of the following areas:
 1. *Applied Mathematics*: 410 (3), 411 (3), 435 (3), 436 (3), 437 (3), 438 (3)
 2. *Pure Mathematics*: 442 (3), 455 (3), 456 (3), 461 (3), 471 (3), 472 (3)
 3. *Operations Research and Statistics*: 415 (3), 483 (3), 484 (3), 486 (3), 488 (3)
- *Electives outside mathematics*: A minor in another department or at least 18 related credit hours outside mathematics approved by the advisor.
- *Science or Engineering Elective*: Eight (8) credit hours from the science and engineering disciplines beyond the general degree requirements.
- *Minimum of 130 credit hours coursework*: Electives to complete the minimum of 130 credit hours.

Sample Curriculum Notes: General education requirements should be fulfilled as early as possible. The sequence MATH 352, 372 is a key prerequisite to many advanced courses and should be taken as early as possible, in no case later than the junior year.

Sample Curriculum for the Bachelor of Science in Mathematics

Semester 1

- 4 MATH 131 (calculus)
- 4 CHEM 121, 121L, 121 R (general chemistry)
- 4 Science/Engineering Elective
- 3 ENGL 111 (college English)
- 15 Total credit hours

Semester 2

- 4 MATH 132 (calculus)
- 4 CHEM 122, 122L, & 122R (general chemistry)
- 4 Science/Engineering Elective
- 3 ENGL 112 (college English)
- 1 Elective
- 16 Total credit hours

Semester 3

- 3 MATH 254 (intro to linear algebra)
- 4 MATH 231 (calculus)
- 5 Phys 121 & 121L
- 3 Humanities
- 1 Electives
- 16 Total credit hours

Semester 4

- 3 MATH 335 (ordinary differential equations)
- 3 MATH 352 (basic concepts)
- 5 PHYS 122 & 122L (general)
- 4 CSE 113 or ES 111
- 1 Electives
- 16 Total credit hours

Semester 5

- 3 MATH 372 (basic concepts of analysis)
- 3 MATH 336 (intro to partial differential equations)
- 4 MATH 382 & 382L (probability & statistics)
- 3 Social Science
- 4 Electives*
- 17 Total credit hours

Semester 6

- 3 MATH 454 (linear algebra)
- 3 ENGL 341 (technical writing)
- 3 Math Elective
- 7 Electives*
- 16 Total credit hours

Semester 7

- 3 MATH 430 (mathematical modeling)
- 3 Math Elective
- 3 Social Science
- 7 Electives*
- 16 Total credit hours

Semester 8

- 3 Math Elective
- 3 Math Elective
- 3 Humanities/Social Science
- 7 Electives*
- 16 Total credit hours

* Choice of electives must include courses for approved 18-hour sequence. It is strongly recommended that elective choices include advanced science and/or a foreign language.

Minor in Mathematics

Minimum credit hours required—18

The following courses are required:

- MATH 254 (3), 335 (3), 352 (3), 382 (3)
- Six (6) additional hours of upper-division mathematics

Graduate Program**Master of Science in Mathematics**

A program fulfilling the general requirements must be completed. Two basic plans are offered: for the program without thesis, MATH 590 (three credit hours) must be completed; for the program with thesis, MATH 591 (six credit hours) must be completed. There is no foreign language requirement for either program. The student must fulfill the requirements for the undergraduate program in mathematics. In addition, the student must fulfill the requirements of one of the following three specializations. Students interested in continuing for the PhD in Applied and Industrial Mathematics should take care to choose their courses so that they will fit that program as well.

Five-Year Bachelor's/Master's Degree Program in Mathematics

The five-year mathematics B.S./M.S. program provides the student the opportunity to obtain both a bachelor's degree and a master's degree in mathematics in five years. A minimum of 158 total credit hours are required to complete the dual degree program.

Students should apply to the program before their seventh semester. Admission is contingent on academic performance and acceptance of a proposed course of study. Graduate status is granted upon completion of the general requirements for the bachelor's degree in mathematics or one of its options with a 3.0 minimum cumulative grade point average. The master's degree is granted upon completion of the requirements of the master's degree program.

The student will work with a professor in the Mathematics Department who will assist the student in developing the course of study and advise the student on their master's thesis or independent study.

Master of Science in Mathematics with Specialization in Industrial Mathematics

Industry and business provide many areas for the application of advanced mathematics, and many possibilities for mathematicians to make significant contributions. New Mexico Tech offers a program to prepare students for these opportunities. Students need a basic background in numerical analysis, differential equations, and statistics at the undergraduate level. The graduate requirements are:

- 1) Modeling courses (6 credits): MATH 430 (Mathematical Modeling); MATH 530 (Modeling Case Studies)
- 2) Core industrial mathematics courses (6 credits)—two of the following: MATH 511 (Numerical Methods); MATH 518 (Nonlinear Programming); MATH 532 (Perturbation Methods); MATH 535 (Mathematical Physics); MATH 587 (Time Series)

- 3) A concentration of four related courses (12 credits), at least two at the 500-level (beyond the two in requirement 2) and at least two in another department, and additional courses to satisfy the general requirements of the Master of Science degree. The courses to satisfy this requirement must be approved by the Industrial Mathematics group.
- 4) Each student spends one term, usually summer, in an internship in an industrial position. This internship is arranged by the student, with the approval of the Industrial Mathematics group and should involve mathematical modeling, computation and analysis.

Industrial Mathematics Committee

Aitbayev—Numerical Methods for Partial Differential Equations, Numerical Analysis
 Avramidi—Mathematical Physics, Analysis on Manifolds, Quantum Field Theory
 Borchers—Optimization, Inverse Problems
 Sharples—Applied Analysis, Asymptotic Expansions
 Starrett—Dynamical Systems, Physics Models, Knot Theory
 Stone—Differential Equations, Mathematical Biology, Industrial Mathematics

Master of Science in Mathematics with Specialization in Operations Research and Statistics

An interdisciplinary program in operations research and statistics is available at the graduate level within the various departments at New Mexico Tech. To specialize in this area, the student must fulfill the requirements for the undergraduate program in mathematics and complete MATH 415, 483, and one of either MATH 486 or 488, or the equivalent.

Graduate work would consist of:

- 1) A minimum of 12 credit hours from MATH 515, 516, 517, 518, 519, 582, 583, 586, 587, 588, 589. At least one course (three credit hours) must be chosen from MATH 515, 517, or 518.
- 2) Additional courses subject to the approval of the student's advisor to complete the requirements of the Graduate School. Related courses include ES 316; MGT 462, 472, 473; MATH 384, 386, 410, 411, 484, 505, and 521.

Master of Science in Mathematics with Specialization in Analysis

To specialize in this area the student must fulfill the requirements of the undergraduate program in mathematics and complete Math 435 and Math 471 or the equivalent.

Graduate work consists of:

- 1) A minimum of 12 credits from Math 531, 533, 534, 535, 536, 537, 575, 576, and 577.
- 2) Additional courses subject to the approval of the student's advisor to complete the requirements of the Graduate School.

Doctor of Philosophy in Applied and Industrial Mathematics

Students of exceptional ability, as demonstrated in a master's degree program or in previous courses, may pursue a program leading to the doctoral degree. Although the master's degree is not a requirement for the Ph.D. degree, the experience gained in writing a master's thesis or independent study project is valuable.

Degree Requirements

- Up to 30 hours from a master's degree, excluding thesis and S/U courses, may be included.
- 48 hours of coursework approved by the student's advisory committee, including:
- All of the following, if not already taken: MATH 410, 411, 435, 437, 438, 471
- 500-level MATH courses (30 credit hours) consisting of:
 1. MATH 530 (3), 532 (3)
 2. Six (6) credit hours of core classes: MATH 511, 535, 538, 539, 577
 3. Four or more of the remaining classes are to be additional core classes (above), courses from the list of recommended classes (below) or other classes approved in advance by the student's committee. Students are strongly encouraged to include MATH 509, Graduate Internship, in their program.
Recommended classes: MATH 509, 510, 512, 518, 519, 531, 533, 536, 537, 587 or other
- 12 hours of upper-division or graduate-level courses from outside the math department
- Dissertation (24 credit hours): MATH 595
- Preliminary exams in differential equations, analysis, and numerical analysis (usually taken in the third semester, or in the second semester for students who already have a master's degree). Students may, if necessary, repeat one or more exams the following semester. Students who do not receive satisfactory scores after two attempts will not be accepted into the PhD program.

Graduate Minor in Applied & Industrial Mathematics

The following courses are required:

- MS Level: Two of Math 430, 437, 438 and
 Two of Math 530, 431, 532, 533, 535,
 537, 538, 539
- PhD Level: MS requirements plus two more of the
 listed 500 level courses

Graduate Minor in Operations Research & Statistics

The following courses are required:

- MS Level: Math 415, 483, and
Two of Math 515, 516, 517, 518, 519, 582,
583, 586, 587, 588, 589
- PhD Level: MS requirements plus two more of the
listed 500 level courses

Graduate Minor in Numerical Analysis

The following courses are required:

- MS Level: Math 410, 411, and
Two of Math 510, 511, 512, 513
- PhD Level: MS requirements plus two more of the
listed 500 level courses

Graduate Minor in Analysis

The following courses are required:

- MS Level: Math 435, 442, 471, and
Two of Math 531, 533, 534, 535, 536, 537,
575, 576, 577
- PhD Level: MS requirements plus two more of the
listed 500 level courses

Mathematics Courses:

Tech's mathematics department offers courses in eight sub-fields of mathematics. The middle digit of each mathematics course number specifies the sub-field in which that course belongs. The middle digits and the sub-fields they represent are:

- 1—operations research and numerical methods
- 2—discrete mathematics
- 3—applied analysis
- 4—geometry
- 5—modern algebra
- 6—topology
- 7—real analysis (theory)
- 8—probability, statistics, stochastic processes

Thus, 415 is a course in operations research, etc. The middle digit 0 is used for the basic mathematics courses. The only exception to this system is MATH 581, the standard college number for directed studies.

MATH 101, College Algebra, 3 cr, 2 cl hrs, 3 lab hrs

The fundamental algebraic operations—factoring, fractions, linear equations and inequalities, quadratic equations, ratio, proportion, variation, functions and their graphs, systems of equations. [NMCCNS MATH 1113: General Education Area II]

MATH 103, 103D, Pre-Calculus, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: ACT Math score of at least 21 or SAT Math score of at least 500 or a score of 24 or higher on the algebra portion of the math placement test, or MATH 101 passed with grade C- or better

Functions and relations, equations and inequalities, determinants and matrices, simultaneous equations, algebra of polynomials, complex numbers. [NMCCNS MATH 1613: General Education Area II]

MATH 104, 104D, Trigonometry, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: MATH 103 passed with a grade of C- or better, or ACT Math score of at least 26 or SAT Math score of at least 590 or a score of 20 or higher on the advanced algebra portion of the math placement test.

Trigonometric functions, identities, related angles, radian measure, graphs, inverse functions, trigonometric equations, logarithms, solution of plane triangles. [NMCCNS MATH 1114: General Education Area II]

MATH 105, Pre-Calculus with Trigonometry, 5 cr, 4 cl hrs, 3 lab hrs

Prerequisites: Same as for MATH 103

Offered summers only. Class consists of five 25-minute lectures and five 55-minute labs each week of summer session.

A condensed course covering most of the topics of MATH 103 and 104. A maximum of six credits will be allowed for any combination of MATH 103, 104, 105.

MATH 131, Calculus and Analytic Geometry I, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: MATH 103 and 104 or the equivalent passed with grade C- or better; or ACT Math score of at least 30 or SAT Math score of at least 670; or a score of at least 20 on the calculus readiness math placement test; or MATH 104 and either ACT Math score of at least 26 or SAT Math score of at least 590.

First course in calculus and analytic geometry. Includes introductory concepts in analytic geometry, limits, continuity, differentiation, applications of the derivative, the mean value theorem, the definite and indefinite integral, and applications of integration. [NMCCNS MATH 1614: General Education Area II]

MATH 132, Calculus and Analytic Geometry II, 4 cr, 4 cl hrs

Prerequisite: MATH 131 passed with grade C- or better

Continuation of MATH 131. Transcendental functions, techniques of integration, polar coordinates, infinite series, and applications. [NMCCNS MATH 1623: General Education Area II]

MATH 221, Formal Logic and Discrete Mathematics, 3 cr, 3 cl hrs

Prerequisite: MATH 132 passed with a grade C- or better

Analytical reasoning and critical thinking skills. Induction and recursion. Mathematical proofs. Propositional calculus and predicate calculus. Discrete and combinatorial mathematics: sets, functions, relations, trees, and graphs, permutations and combinations.

MATH 231, Calculus and Analytic Geometry III, 4 cr, 4 cl hrs

Prerequisite: MATH 132 passed with grade C- or better

Vectors in the plane and 3-space, vector calculus in two dimensions, partial differentiation, multiple integration, topics in vector calculus, and complex numbers and functions.

MATH 254, Introduction to Applied Linear Algebra, 3 cr, 3 cl hrs, 1.5 lab hrs

Prerequisite: MATH 131 passed with grade C- or better

Solution of linear systems. Matrix algebra. Rank. Determinants. Eigenvalues and eigenvectors. Numerical aspects of matrix calculation. Introduction to vector spaces and linear transformations. Applications. (Same as BCS 254)

MATH 283, Introduction to Applied Statistics, 3 cr, 3 cl hrs, 1.5 lab hrs

Corequisite: MATH 132

Exploratory data analysis. Introduction to probability and random variables. Concepts of population and sample. Estimation and hypothesis testing. Simple linear regression and one-way analysis of variance. Techniques in data analysis using statistical computer packages. (Same as BCS 283)

MATH 332, Vector Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 231 passed with grade C- or better

Scalar and vector fields, gradient, divergence, curl, del operator, general orthogonal curvilinear coordinates, line integrals, surface and volume integrals, divergence theorem, Green's theorem, Stokes's theorem, applications.

MATH 335, Ordinary Differential Equations, 3 cr, 3 cl hrs

Prerequisite: MATH 132 passed with grade C- or better

Solution methods for first order ordinary differential equations of various types, including separable, linear, Bernoulli and exact. Solution methods for second (and higher) order linear differential equations with constant coefficients. Series solutions. Laplace transforms. Applications.

MATH 335L, Ordinary Differential Equations Computer Lab, 1 cr, 1 cl hr

Corequisite: MATH 335 or equivalent.

Optional lab to accompany MATH 335. Basic introduction to the "Maple" syntax required to solve ordinary differential equations with computers. Emphasis on modeling, using graphing capabilities to illustrate how responses (solutions) are influenced by changes in the initial data and physical parameters.

MATH 336, Introduction to Partial Differential Equations, 3 cr, 3 cl hrs

Prerequisites: MATH 231, 254 and 335, each passed with grade C- or better

Orthogonal functions, Sturm-Liouville theory, Fourier series and integrals, heuristic derivation of examples of partial differential equations taken from heat conduction, vibration problems, electromagnetism, etc.; separation of variables, application to boundary value problems.

MATH 337, Engineering Mathematics, 3 cr, 3 cl hrs

Prerequisites: MATH 231

Corequisite: MATH 335

Selected topics from linear algebra are discussed, including vectors, matrices, determinants, Gaussian elimination, vector spaces and basis as well as Eigenvalues, eigenvectors and diagonalization of matrices. Of particular interest will be linear algebra techniques which are utilized of solving systems of (linear) algebraic equations and solving systems of coupled ordinary differential equations using Laplace transforms and linear algebra tools.

MATH 352, Basic Concepts of Mathematics, 3 cr, 3 cl hrs

Prerequisite: MATH 132 passed with grade C- or better

Mathematical proofs, set theory, mathematical induction and recursion, binary relations, functions, definition and development of some common number systems, cardinal numbers, abstract algebra.

MATH 372, Basic Concepts of Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 352 or equivalent passed with grade C- or better

Real numbers, sequences, limits, continuity, uniform continuity, differentiation, Reimann integral.

MATH 382, Probability and Statistics, 3 cr, 3 cl hrs

Prerequisite: MATH 132 passed with grade C- or better

Exploratory data analysis, random variables, estimation and hypothesis testing, linear regression and analysis of variance, basic concepts of discrete and continuous probability distributions, bivariate probability distribution functions, expected values, moment generating function and weak law of large numbers. Uses of the central limit theorem and its applications. This course provides an introduction to probability theory and statistical inference. The theory of probability is the primary mathematical tool used in statistical inference and therefore this course will concentrate heavily on probability and statistics. The course has been designed for computer science and engineering students; however, it is broad enough for students from outside these disciplines.

MATH 382L, Probability and Statistics Lab, 1 cr, 1 cl hrs

Corequisite: Math382 or equivalent

Entering data, descriptive statistics, graphing data, cross tabulation, hypothesis testing, and calculation of probabilities from different probability distributions. Each lab introduces a problem, provides some scientific background, suggests investigations for the data, and provides a summary of the theory used in the investigations.

MATH 383, Introduction to Biostatistics, 3 cr, 3 cl hrs

Prerequisite: Math 132 passed with a grade of C- or better

This course covers the fundamental statistical concepts related to the practice of public health: descriptive statistics, design of biological research studies, probability, sampling, statistical distributions, confidence intervals, hypothesis testing, comparison of means and proportions, chi-squared tests, one-way & two-way ANOVA, simple and multiple linear regression, Fisher's Exact test and Mantel-Hansel test for comparing several 2x2 tables. The course also uses the R statistical software and includes many applications of statistics to health sciences and medical studies, emphasizing concepts and interpretation of results. Optional topics: principal components and factor analysis.

MATH 384, Applied Regression and Design of Experiments, 3 cr, 3 cl hrs

Prerequisite: MATH 283 or 382 passed with grade C- or better

Design of experiments, analysis of variance and covariance, linear and nonlinear curve fitting. Applications taken from metallurgy, mining and petroleum engineering, hydrology, and other disciplines.

MATH 386, Nonparametric Statistics, 3 cr, 3 cl hrs

Prerequisite: MATH 283 or 382 passed with grade C- or better

Tests based on ranks for one-sample and two-sample problems, nonparametric estimates, multiple comparisons, nonparametric methods in regression. Applications in science and engineering.

MATH 391, Special Studies, hrs and cr to be arranged**MATH 401, Putnam Competition, 1 cr, 1 cl hr**

Graded S/U

Students in this course will prepare for and then participate in the annual William Lowell Putnam Competition in mathematics. In preparation for the competition, students will learn problem-solving strategies and practice on problems from previous competitions. May be taken multiple times for credit.

MATH 410, Numerical Methods for Scientists and Engineers I, 3 cr, 3 cl hrs

Prerequisite: CS 113 or ES 111

Corequisite: MATH 335

Floating point arithmetic, solution of linear and nonlinear systems of equations, interpolation, numerical differentiation and integration, numerical solution of ordinary differential equations.

MATH 411, Numerical Linear Algebra, 3 cr, 3 cl hrs

Prerequisites: MATH 254; CSE 113 or ES 111

Direct and iterative methods for solving linear systems, conditioning and stability, methods for computing eigenvalues and eigenvectors, linear least squares problems, applications, performance, software.

MATH 414, Introduction to High Performance Computing, 3 cr, 3 cl hrs

Prerequisite: MATH 410 passed with grade C- or better

Solving scientific problems in high-performance computing systems. Topics include: numerical methods, using software libraries and packages such as MATLAB, Mathematica, NAG, LAPACK, etc., matching algorithms to machines, measuring performance and scientific visualization. A number of computing architectures—such as high-performance workstations, the Cray Y-MP, and the Connection Machine—will be used to solve a small set of prototype problems.

MATH 415, Introduction to Operations Research: Deterministic Methods, 3 cr, 3 cl hrs

Prerequisite: MATH 254 passed with grade C- or better

A survey of operations research techniques including linear programming, nonlinear models, and graph theoretical models. (Same as BCS 415)

MATH 430, Mathematical Modeling, 3 cr, 3 cl hrs

Prerequisites: MATH 254 and 335; MATH 382; passed with grade C- or better

Introduction to the process of developing, analyzing, and refining mathematical models. Deterministic and probabilistic models considered for both discrete and continuous problems. Applications to a variety of fields.

MATH 435, Complex Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 336 passed with grade C- or better

Algebra of complex numbers, analytic functions and Cauchy-Riemann equations, complex integration and Cauchy's theorem, integral formulae, power series, residues and contour integration, analytic continuation, Riemann surfaces.

MATH 436, Applications of Complex Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 435 passed with grade C- or better

Topics selected from linear ordinary differential equations in the complex plane, special functions, conformal mapping, Laplace transform, Fourier and Hilbert transforms.

MATH 437, Systems of Ordinary Differential Equations, 3 cr, 3 cl hrs

Prerequisites: MATH 254 and 335, each passed with grade C- or better

Theory and application of systems of ordinary differential equations, linear and nonlinear systems, two-dimensional autonomous systems, stability, periodic solutions and limit cycles, interspecies competition and predator/prey problems, pendulum equation, Duffing equation, Van der Pol equation, Lienard equation.

MATH 438, Partial Differential Equations, 3 cr, 3 cl hrs

Prerequisite: MATH 336 passed with grade C- or better

Classification of classical partial differential equations of mathematical physics, boundary conditions, uniqueness theorems, first and second order equations, characteristics, boundary value problems, Green's functions, maximum principle.

MATH 442, Introduction to Differential Geometry, 3 cr, 3 cl hrs

Prerequisite: MATH 254 passed with grade C- or better

Introduction to the theory of manifolds, vector fields, tensors and differential forms.

MATH 454, Linear Algebra, 3 cr, 3 cl hrs

Prerequisites: MATH 254 and 352, each passed with grade C- or better

Finite dimensional vector spaces. Linear transformations. Equivalence and similarity of matrices. Eigenvectors and eigenvalues, canonical forms.

MATH 455, 456, Introduction to Abstract Algebra, 3 cr, 3 cl hrs each semester

Prerequisite: MATH 352 passed with grade C- or better

A study of abstract algebraic structures, semi-groups, groups, rings, ideals, integral domains, fields, vector spaces, field extensions.

MATH 458, Introduction to Theory of Numbers, 3 cr, 3 cl hrs

Prerequisite: MATH 352 passed with grade C- or better

Properties of integers, primes, congruences, related topics.

MATH 461, Introduction to Topology, 3 cr, 3 cl hrs

Prerequisite: MATH 372 passed with grade C- or better

Fundamental concepts of point-set topology, abstract topological spaces, metric spaces, continuous mappings, separation axioms, compactness, connectedness.

MATH 464, Knot Theory, 3cr, 3 cl hrs

Prerequisite: MATH 335 and MATH 352 passed with grade C- or better

General survey of knot theory concentrating on knot invariants, including numerical, polynomial and invariants of finite type, theory of braids, the Artin braid group, elementary template theory, applications to physics and biology.

MATH 471, 472, Introduction to Analysis, 3 cr, 3 cl hrs each semester

Prerequisite: MATH 372 passed with grade C- or better

Basic concepts of the real-number system, elements of point-set theory, infinite sequences, limits, continuity, differentiation of functions of one variable, Riemann-Stieltjes integral, series, functions of several variables.

MATH 483, Mathematical Statistics, 3 cr, 3 cl hrs

Prerequisite: MATH 382 passed with grade C- or better

Introduction to decision theory. Multivariate distributions. Sampling distributions for the normal case. Convergence of random variables. Different methods of estimation. Principles of hypothesis testing.

MATH 484, Reliability and Quality Control, 3 cr, 3 cl hrs

Prerequisite: MATH 382 passed with grade C- or better

Order statistics, testing and estimation for common lifetime distributions in reliability, accelerated life tests, Bayesian methods in reliability. Statistical techniques of industrial quality control, sampling methods, control charts. Applications in industry.

MATH 486, Introduction to Stochastic Processes, 3 cr, 3 cl hrs

Prerequisites: MATH 254 and 382, each passed with grade C- or better

Conditioning. The Poisson process. Theory of Markov chains, continuous time Markov and semi- Markov processes. Topics from renewal theory and Markov renewal theory. Queuing Theory. Applications in science and engineering. (Same as BCS 486)

MATH 488, Introduction to Operations Research: Probabilistic Methods, 3 cr, 3 cl hrs

Prerequisite: MATH 382, passed with grade C- or better

Monte Carlo Simulation Theory. Application of simulation to problems in science, engineering, and business. Queuing systems simulation. Inventory theory. (Same as BCS 488)

MATH 491, Directed Study, hrs and cr to be arranged**MATH 500, Directed Research, hrs and cr to be arranged****MATH 501, 502, Professional Development Seminar, 3 cr, 3 cl hrs each semester**

A seminar in which students will develop skills in problem solving, communication, and research. Students will be expected to actively participate in the seminar by attending presentations, solving assigned problems, and preparing written and oral presentations. Graded S/U.

MATH 503, Graduate Seminar, 0-1 cr, 1 cl hr

Prerequisite: Graduate standing.

Attend and participate in departmental seminars. Graded on an S/U basis.

MATH 505, Neural Nets, 3 cr, 3 cl hrs

Prerequisites: CS 344; MATH 254 and 382; or consent of instructor

Neuron modeling. The perceptron and multilayer perceptrons. Learning algorithms. The Kohonen model, the Grossberg model, the Hopfield model. Associative memory. Applications. Recent developments in the field. (Same as CSE 565)

MATH 509 Graduate Internship, credit to be arranged

Prerequisite: Graduate standing

MATH 510 Computational Fluid Dynamics, 3 cr, 3 cl hrs

Prerequisite: MATH 254, 336, 410 or equivalent

Equations of fluid dynamics, flow models, discretization techniques, analysis of numerical schemes, numerical methods for solving linear and nonlinear systems of equations, numerical methods for inviscid and viscous flows.

MATH 511, 512, Numerical Methods for Partial Differential Equations, 3 cr, 3 cl hrs each semester

Prerequisite: MATH 410 or consent of instructor

Finite difference methods for parabolic and elliptic partial differential equations. Convergence and stability. Finite element methods. Advanced numerical linear algebra.

MATH 513, Advanced Topics in Numerical Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 410 or consent of instructor

Topics chosen from areas in numerical analysis, numerical partial differential equations, multigrid and domain decomposition methods, numerical linear algebra. May be taken multiple times for credit.

MATH 515, Topics in Deterministic Operations Research, 3 cr, 3 cl hrs

Prerequisite: MATH 415 or consent of instructor

Study of a special topic in deterministic operations research. May be taken multiple times for credit.

MATH 516, Topics in Stochastic Operations Research, 3 cr, 3 cl hrs

Prerequisites: MATH 486 or consent of instructor

Study of a special topic in stochastic operations research. May be taken multiple times for credit.

MATH 517, Combinatorial Optimization, 3 cr, 3 cl hrs

Prerequisite: MATH 415 or consent of instructor

Maximum flow, shortest path, and minimum cost flow problems on networks. Matching. Matroids. Cutting plane and branch and bound methods for integer programming. Computational complexity of combinatorial optimization problems.

MATH 518, Methods of Nonlinear Programming, 3 cr, 3 cl hrs

Prerequisite: MATH 410 or 415 or consent of instructor

Theory of constrained and unconstrained optimization. Methods for nonlinear programming, including quasi-Newton methods, conjugate direction methods, Levenberg-Marquardt methods, sequential quadratic programming, and sequential unconstrained minimization techniques.

MATH 519, 519D, Inverse Problems, 3cr, 3 cl hrs

Theory and practice of the various techniques of inverting geophysical data to obtain models. Primary emphasis is on the understanding and use of linear inverse techniques. (Same as GEOP 529.)

MATH 521, Advanced Combinatorics, 3 cr, 3 cl hrs*Prerequisite: MATH 221*

Graph theory and applications. Graphs, trees, connectivity, Euler tours and Hamiltonian cycles, matchings, planar graphs, directed graphs, networks, cycle space, and bond space.

MATH 530, Modeling Case Studies, 3 cr, 3 cl hrs*Prerequisite: MATH 430 or equivalent*

Open-ended modeling projects from actual applications.

MATH 531, 531D, Topics in Ordinary Differential Equations, 3 cr, 3 cl hrs each semester*Prerequisite: MATH 437 or equivalent*

Study of a special topic in ordinary differential equations not usually treated. Normally one related to a field of research interest at Tech. May be taken multiple times for credit.

MATH 532, 532D, Perturbation Methods, 3 cr, 3 cl hrs*Prerequisite: MATH 437 or equivalent*

A survey of expansion techniques. Regular and singular perturbations. Poincaré-Linstedt method. Matched asymptotic expansions. Multiple scales.

MATH 533, 534, Topics in Partial Differential Equations, 3 cr, 3 cl hrs each semester*Prerequisite: MATH 438 or equivalent*

Study of a special topic in partial differential equations not usually treated. Normally one related to a field of research interest at Tech. May be taken multiple times for credit.

MATH 535, 536, Methods of Mathematical Physics, 3 cr, 3 cl hrs each semester*Prerequisite: MATH 436*

Advanced topics selected from asymptotic expansions of integrals and ordinary differential equations, integral equations, singular integral equations, Wiener-Hopf technique, generalized functions.

MATH 537, 537D, Bifurcation Theory, 3 cr, 3 cl hrs*Prerequisite: MATH 437 or equivalent*

Discrete and continuous models. Nonlinear buckling, expansion of the bifurcated solution, stability analysis, Hopf bifurcation, degree theory, the Rabinowitz theorem, and other topics.

MATH 538, 538D, Wave Phenomena, 3 cr, 3 cl hrs*Prerequisite: MATH 438 or equivalent or consent of instructor*

Hyperbolic and dispersive waves. Characteristic methods, breaking and shock fitting, and weak solutions. Examples drawn from water waves, traffic flow problems, supersonic flight, and other areas.

MATH 539, 539D, Fluid Dynamics, 3 cr, 3 cl hrs*Prerequisite: MATH 438 or equivalent*

The Navier-Stokes equations, inviscid flow, irrotational fluids, viscosity, and turbulence. Other topics as time and interest permit.

MATH 542, Topics in Differential Geometry, 3 cr, 3 cl hrs*Prerequisite: MATH 442 or consent of instructor*

Study of advanced topics in differential geometry such as: Brouwer degree, fundamental group, homology groups, De Rham cohomology, Betti numbers, fibre bundles, Morse theory, Lie groups, covering spaces, homotopy groups. May be taken multiple times for credit.

MATH 561, 562, Topology, 3 cr, 3 cl hrs each semester*Prerequisites: MATH 471, 472; or MATH 461*

Point-set topology, abstract topological spaces, generalized convergence, product and quotient spaces, metric spaces, uniform spaces; elementary concepts of algebraic topology.

MATH 575, 576, Functions of a Real Variable, 3 cr, 3 cl hrs each semester*Prerequisites: MATH 471, 472; MATH 461 or MATH 561 recommended*

Topological concepts, category, measure theory, Lebesgue measure and integration, derivatives and the Radon-Nikodym theorem, product spaces and measures, function spaces, normed linear spaces.

MATH 577 Functional Analysis, 3 cr, 3 cl hrs*Prerequisite: MATH 471 or equivalent*

Normed vector spaces, Banach spaces, Banach fixed point theorem. Lebesgue integral, Lebesgue measure. Hilbert spaces and orthonormal systems, strong and weak convergence. Linear operators on Hilbert spaces, self-adjoint operators, compact operators, spectral theory, Fourier transform. Applications to integral and differential equations, Fredholm theory. Distributions and partial differential equations, fundamental solutions, resolvent, Green's functions, weak solutions.

MATH 581, Directed Study, hrs and cr to be arranged

An advanced course offered on demand under the guidance of a senior staff member.

MATH 582, Linear Statistical Models with Applications, 3 cr, 3 cl hrs

Prerequisite: MATH 483 or consent of instructor

An in-depth study of regression and analysis of variance models. Topics include multiple regressions and model building, analysis of residuals, analysis of variance as regression analysis, generalized linear models, generalized linear mixed models, nonlinear models, multi-factor models with equal and unequal sample sizes, random and fixed effects models, randomized complete block designs, and analysis of covariance. The statistical packages SAS and Minitab will be used for data analysis.

MATH 583, 584, Topics in Probability and Statistics, 3 cr, 3 cl hrs each semester

Prerequisites: MATH 384 or 483; MATH 486 or consent of instructor

Advanced topics selected from linear regression analysis, the design of experiments, decision theory. Bayes and empirical Bayes procedures. Markov chains, Markov and semi-Markov processes, renewal theory. May be taken multiple times for credit.

MATH 585, Statistics for Technology Managers, 3 cr, 3 cl hrs

Prerequisite: Enrollment in the Engineering Management program

Probability and random variables; simple and multiple linear regression using least squares and other methods; experimental design; other topics including nonlinear regression; applications to decision making.

MATH 586, 586D, Spatial Variability and Geostatistics, 3 cr, 3 cl hrs

Prerequisite: MATH 382

Introduction to spatial and temporal variability. Stationary and intrinsic random fields, variograms and estimation. Kriging, co-kriging, and simulation of random fields. Conditioning and conditional simulation. Indicator kriging and simulation. Applications from hydrology, mining, petroleum engineering, and other fields of science and engineering.

MATH 587, 587D, Analysis of Time Series and Spatial Data, 3 cr, 3 cl hrs

Offered in alternate years

An introductory overview of methods for analyzing temporal and spatial series with an emphasis on scientific applications. Linear systems in continuous and discrete time, Fourier analysis, spectral estimation, convolution and deconvolution, filtering, the z and Laplace transforms, stationary and nonstationary time series, ARIMA modeling, forecasting, and generalizations to multidimensional and multichannel applications. (Same as HYD 587 and GEOP 505)

MATH 588, Advanced Data Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 483 or consent of instructor

Topics include linear regression, inferential tools for regression, model checking and refinement, experimental design, repeated measures and other multivariate responses, comparisons of proportions or odds, logistic regressions and power analysis. Principal components and factor analysis are also introduced.

MATH 589, Applied Multivariate Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 382; MATH 283 or 384 recommended

Multivariate normal distribution and tests assessing multivariate normality. Estimation and hypotheses testing regarding the parameters of multivariate normal populations. Principal component analysis, factor analysis, canonical correlations analysis, classification and discriminant analysis, cluster analysis, multivariate linear models, and multivariate analysis of variance and covariance. Applications in science and engineering.

MATH 590, Independent Study, cr to be arranged

Under the direction of a faculty member appointed by the department, the student shall prepare a paper making use of standard reference sources on some topic not covered by other course work.

MATH 591, Thesis (master's program), cr to be arranged

MATH 595 Dissertation (doctoral degree program), credit to be arranged

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Faculty Research Interests

Aitbayev—Numerical Methods for Partial Differential Equations, Numerical Analysis
 Avramidi—Mathematical Physics, Analysis on Manifolds, Quantum Field Theory
 Borchers—Optimization, Inverse Problems
 Hossain—Multivariate Analysis, Survival Analysis, Estimation Reliability and Regression Diagnostics.
 Kerr—Thermoelasticity, Integral Equations, Applied Mathematics
 Makhnin—Stochastic Processes, Statistics
 Starrett—Dynamical Systems, Physics Models, Knot Theory
 Stone—Differential Equations, Mathematical Biology, Industrial Mathematics
 Wang—Partial Differential Equations, Dynamical Systems, Applied Mathematics
 Zhang—Applied Mathematics, Mathematical Biology, Dynamical Systems and Differential Equations

Optical Science and Engineering

Advisory Board Members:

Fuierer (Materials Engineering)

Teare (Electrical Engineering)

Wedeward (Electrical Engineering)

Westpfahl (Physics)

Offered: Minor in Optical Science and Engineering

Students in the minor program in Optical Science and Engineering receive a broad introduction to optics as well as to specialized applications related to optical research activities on campus. The areas of research at New Mexico Tech include adaptive optics, interferometry, wavefront propagation, atmospheric turbulence, polarimetry and applications to directed energy, astronomy and communications. The prime optical research site at New Mexico Tech is the Magdalena Ridge Observatory (MRO), a dedicated astronomical observatory that will support a large optical interferometer and a 2.4m single telescope. This facility provides a world-class facility for scientific research in optics, optical controls and astronomical science applications. On campus, the Etscorn Observatory provides access to commercial telescopes and imaging cameras.

A Tech student may earn a minor in Optical Science and Engineering as part of a Bachelor of Science degree. While fulfilling the requirements for a Bachelor of Science degree the student must complete a minimum of ten (10) hours of core optics courses, three (3) hours of electromagnetic theory, and at least five (5) additional hours from approved optional courses.

Minor in Optical Science and Engineering

Minimum credit hours required—18

- OPT 300 (4), OPT 400 (3), OPT 410 (3)
- One of: PHYS 333 (3); EE 333 (3); MATE 447 (3)
- Two of: EE 308 (3), EE 324 (3), EE 434 (3); MATE 441 (3), MATE 452 (3); PHYS 334 (3), PHYS 362 (2), PHYS 444 (3); OPT 420 (3), OPT 430 (3), OPT 460 (3), OPT 490 (2).

Course Descriptions

OPT 300, Introduction to Optics, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: PHYS 122 or 132; MATH 231

An introduction to geometrical optics, aberration theory, image formation, Fourier optics, radiometry and photometry and engineering practice in working with optical systems. The course will also introduce optical fabrication concepts and optical coatings.

OPT 400, Mathematical and Computational Optics, 3 cr, 3 cl hrs

Prerequisites: OPT 300; MATH 254

A mathematical approach to optics introducing standard aberration and optical calculation techniques. Topics include paraxial optics, polarization matrices, Seidel aberrations, ray tracing and wavefront propagation through materials. Students will be introduced to modern ray tracing tools.

OPT 410, Advanced Optics, 3 cr, 3 cl hrs

Prerequisite: OPT 400

Topics include image evaluation, wavefront propagation, mode analysis, interferometry, spectrometers, optical testing and multilayer dielectric coatings.

OPT 420, Interferometry and Optical Testing, 3 cr, 3 cl hrs

Prerequisite: OPT 400 or consent of instructor.

An advanced course in optical testing and interferometric systems.

OPT 430, Thin Films, 3 cr, 3 cl hrs

Prerequisite: OPT 400 or consent of instructor.

An advanced course in designing and using thin film coatings.

OPT 460, Optical Laboratory, 3 cr, 6 lab hrs

Prerequisite: OPT 300

An advanced laboratory in optics and photonic systems.

OPT 490, Special Topics in Optics, cr and topics arranged

Prerequisite: OPT 300

Special topics course in optics. Topics may include lasers, fiber optics, adaptive optics and other subjects of interest.

Physical Recreation

The Physical Recreation program provides students with the opportunity to take part in a wide variety of sports and activities. Classes entail basic skill instruction, and participation is required for credit.

PR classes are generally offered for one credit and are dependent upon student interest and the availability of instructors.

For a complete listing of current Physical Recreation offerings, visit <http://ced.nmt.edu> or call (575) 835.6581.

Physical Recreation Courses:

The following sample PR courses are graded S/U and may be used for elective credit only. Classes may be taken multiple times for credit.

P R 100C Weight Lifting 1 cr, 2 cl hrs

Introduction to basic principles and techniques of weight training

P R 101C Weight Lifting for Women 1 cr, 2 cl hrs

Introduction to basic principles and techniques of weight training as related to women

P R 102C Physical Conditioning 1 cr, 2 cl hrs

Physical fitness, stress management, weight management, nutrition and muscular strength and endurance

P R 103C Beginning Racquetball 1 cr, 2 cl hrs

Basic fundamentals of all strokes and strategies used in the game of racquetball

P R 203C Intermediate Racquetball 1 cr, 2 cl hrs

Prerequisite: PR 103C or consent of instructor.

Perfection of all strokes and strategies used in the game of racquetball

P R 104C Beginning Tennis 1 cr, 2 cl hrs

Fundamentals skills in footwork, forehand, back hand, volleys, and servings

P R 105C Badminton 1 cr, 2 cl hrs

Instruction in basic skills such as serving, volleys, forehand and backhands

P R 106C Beginning Golf 1 cr, 2 cl hrs

Instruction in the basic skills, equipment, rules, etiquette and shot-making and use of irons and woods.

P R 206C Intermediate Golf 1 cr, 2 cl hrs

Prerequisite: PR 106C or consent of instructor.

Instruction emphasizing actual play

P R 110C Beginning Volleyball 1 cr, 2 cl hrs

Introduction to basic skills, rules, and strategies

P R 210C Intermediate Volleyball 1 cr, 2 cl hrs

Prerequisite: Prior experience is required.

Improve individual skill levels and apply more tactics and strategies

P R 111C Basketball 1 cr, 2 cl hrs

Instruction and practice of game skills in a team setting

P R 112C Indoor Soccer 1 cr, 2 cl hrs

Instruction and practice of basic skills in an indoor setting

P R 113C Flag Football 1 cr, 2 cl hrs

Instruction and practice of basic skills, rules, field positions in a team setting

P R 124C Stretch and Relaxation 1 cr, 2 cl hrs

Instruction emphasizes stretch and relaxation techniques

P R 130C Aerobics 1 cr, 2 cl hrs

Instruction in continuous movement using basic steps for improved cardio respiratory endurance.

P R 131C Salsa Aerobics 1 cr, 2 cl hrs

Instruction emphasizes exercise and cardiovascular endurance with the use of Latin music

P R 132C Zumba 1 cr, 2 cl hrs

The trademark name for Salsa Aerobics instruction emphasizing exercise and cardiovascular endurance with the use of Latin music

P R 133C Indoor Cycling 1 cr, 2 cl hrs

Designed to progressively build strength and endurance while improving cardio respiratory function

P R 134C Spinning 1 cr, 2 cl hrs

The trademark name for Indoor Cycling designed to progressively build strength and endurance while improving cardio respiratory function

P R 140C Beginning Kung Fu 1 cr, 2 cl hrs

Foundations of Chinese martial arts, self defense, and health systems with special emphasis on the Northern Longfist style.

P R 141C Karate 1 cr, 2 cl hrs

Instruction in the basic skills, blocks, strikes, and kicks of Japanese karate

P R 142C Taijutsu 1 cr, 2 cl hrs

Instruction in the basic techniques of punching, falling, rolling and kicking in Taijutsu

P R 143C Tai Chi Chuan 1 cr, 2cl hrs

Instruction and practice in techniques to enhance body awareness, reduces stress, improve balance and increase strength.

P R 150C Beginning Belly Dance 1 cr, 2 cl hrs

Instruction in the basic moving steps and rhythms of the belly dance

P R 151C Irish Step Dance 1 cr, 2 cl hrs

Introduction to the traditional Irish step dance

P R 152C Ballroom Dance 1 cr, 2 cl hrs

Introduction to ballroom dance such as the lindy, foxtrot, waltz, tango, cha-cha and rumba

P R 153C Swing Dance 1 cr, 2 cl hrs

Introduction to swing dancing including East Coast Swing, Lindy Hop and Charleston.

P R 160C Outdoor Rec 1 cr, 2 cl hrs

Prerequisite: Good Physical Condition and able to hike several miles on rough terrain.

Selected outdoor activities such as rappelling, rock climbing, paddling, caving, and hiking

P R 161C Beginning Rock Climbing 1 cr, 2 cl hrs

Introduction to basic climbing technique with an emphasis on safety, safe knot and belay

P R 170C Aquatic Fitness 1 cr, 2 cl hrs

Prerequisite: Swimsuits and Aqua shoes recommended
Designed to enhance the level of muscular development, and cardiovascular endurance through exercise in water

P R 250C Intermediate Belly Dance 1 cr, 2 cl hrs

Instruction on the isolation and slow movements of Middle

Eastern dance, including use of the veil and improvisation

P R 261C Intermediate Rock Climbing 1 cr, 2 cl hrs

Prerequisite: PR 161C or consent of instructor
Continuation of safety, rope set-up, belaying lead climb, rappelling and anchor set-up

Physics

Professors Hofner, Minschwaner, Raymond, Romero, Sonnenfeld, Westpfahl, Young
Associate Professors Creech-Eakman (Chair of the Department), Eack, Meier, Morales-Juberias, Sessions
Assistant Professor Arendt
Adjunct Faculty: Avramidi, Buscher, Butler, Elias, Elvois, Fuchs, Goss, Haniff, Jurgenson, Lopez Carrillo, Manney, Myers, Ott, Owen, Rison, Rupen, Swain, Teare, Thomas, Wozniak
Emeritus Professors Eilek, Hankins, Klinglesmith, Krehbiel, LeFebre, Meason, Schery, Winn

Degrees Offered: *B.S. in Physics and in Physics with options in Astrophysics, Atmospheric Physics, or Computer Science; M.S. in Physics; M.S. in Physics with Specialty in Instrumentation; Ph.D. in Physics; Ph.D. in Physics with dissertation in Astrophysics, Atmospheric Physics, or Mathematical Physics*

Departmental web site: <http://www.physics.nmt.edu>

Students in the Department of Physics are encouraged to pursue a broad scientific background and to master theory as well as experiment. The fundamental courses are offered in the principal areas of physics—atomic and nuclear physics, classical mechanics, electricity and magnetism, optics, quantum mechanics, statistical physics, and thermodynamics. The department also offers several laboratory classes. There is the opportunity for students to participate in research projects during the semesters and the summertime, over and above the class and lab work. Many undergraduate students become involved in faculty research and often co-author published papers.

There are three options to accompany the basic physics undergraduate degree: astrophysics, atmospheric physics, and computer science. The first two are designed around the main research interests of the faculty, so students can take advantage of the expertise of the faculty and the facilities that are offered on or near the campus. The latter option is present because computers play a crucial role in many applications of physics. In addition, we encourage students to consider a minor in electrical engineering or mathematics. Several of the faculty have expertise in these areas.

The areas of research in atmospheric physics include thunderstorm electricity, precipitation, cloud dynamics, large-scale atmospheric dynamics, and the photochemistry of the middle to upper atmosphere and the dynamics of planetary atmospheres. The Langmuir Laboratory for Atmospheric Research, located on a mountaintop a one hour drive from the campus, offers an unparalleled opportunity for active undergraduate and graduate student participation in observation and research. The atmospheric physics group also operates a Beowulf cluster for atmospheric modeling, the

Lightning Mapping Array, E-field-mill networks, and an active scientific ballooning program focused on charge motion and X-rays produced during storms. In addition, faculty members, as well as undergraduate and graduate students, participate in field programs that use the aircraft and radars of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

Research in astrophysics includes pulsar radio emission, the dynamics and kinematics of nearby galaxies, radio galaxies, plasma astrophysics, stellar evolution, and star formation. The Jansky Very Large Array (VLA) and Very Long Baseline Array (VLBA) radio telescopes, operated by the National Radio Astronomy Observatory (NRAO), are headquartered on campus and offer unique opportunities for research in radio astronomy for faculty and undergraduate and graduate students alike. In addition, the 2.4-meter optical telescope at New Mexico Tech's Magdalena Ridge Observatory (MRO) is now in operation, and the MRO optical interferometer is under construction. This facility is already involving students in research and development activities.

Undergraduate Program

Bachelor of Science in Physics

Minimum credit hours required—130

In meeting the General Education Core Curriculum (page 7), physics majors must choose PHYS 221 and 222 and labs. In addition, the following courses are required:

- PHYS 241 (3), 242 (4), 321 (3), 333 (3), 334 (3), 336L (1), 340 (3), 380 (1), 411 (3), 443 (3), 451 (2)
- MATH 231 (4), 254 (3), 332 (3), 335 (3), 336 (3), and three hours of approved upper-division courses
- Eight hours (with associated labs) from the disciplines of: Biology (BIOL), Earth Science (ERTH), Engineering (ChE, CE, EE, ENVE, MATE, METE, ES, MENG, ME, PETR), Computer Science Engineering (CSE), or PHYS 189 (Introductory Astronomy or Introduction to Weather and Climate). No fewer than 8 credits are required in the lecture/lab pairs. If a lecture/lab pair is taken worth fewer than 4 credits, more than two pairs will need to be taken to satisfy the requirement.
- Language—six hours
- Electives—to complete 130 credit hours; in some instances, additional elective credit hours may be desired.

Sample Curriculum for the Bachelor of Science in Physics

Semester 1

- 4 Electives
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 15 Total credit hours

Semester 2

- 4 PHYS 121
- 4 MATH 132 (calculus)
- 4 CHEM 122 & 122L (general)
- 3 ENGL 112 (college English)
- 15 Total credit hours

Semester 3

- 5 PHYS 221 & 221L
- 3 PHYS 241 (computational)
- 4 MATH 231 (calculus)
- 3 Social Science
- 3 Language
- 18 Total credit hours

Semester 4

- 5 PHYS 222 & 222L
- 4 PHYS 242 (waves)
- 3 MATH 332 (vector analysis)
- 3 MATH 335 (ordinary differential equations)
- 3 Humanities (Language)
- 18 Total credit hours

Semester 5

- 3 PHYS 321 (mechanics)
- 3 PHYS 333 (electricity & magnetism)
- 3 MATH 254 (linear algebra)
- 4 Biology/Earth Science/Engineering with lab
- 3 ENGL 341 (technical writing)
- 16 Total credit hours

Semester 6

- 3 PHYS 334 (radiation and optics)
- 1 PHYS 336L (electrical & magnetic measurements lab)
- 3 PHYS 340 (quantum theory)
- 1 PHYS 380 (practicum in problem solving)
- 4 Biology/Earth Science/Engineering with lab
- 3 Social Science
- 1 Electives
- 16 Total credit hours

Semester 7

- 3 PHYS 411 (thermodynamics)
- 3 PHYS 443 (atomic and nuclear)
- 3 MATH 336 (applied analysis)
- 3 Humanities
- 3 Social Science
- 3 Electives
- 18 Total credit hours

Semester 8

- 2 PHYS 451 (senior lab)
- 3 Humanities/Social Science
- 6 Electives
- 3 MATH 382 (probability & statistics)
- 14 Total credit hours

Bachelor of Science in Physics with Astrophysics Option

Minimum credit hours required—130

In meeting the General Education Core Curriculum (page 7), physics majors must choose PHYS 221 and 222 and labs. Requirements include the courses listed above for the Bachelor of Science Degree in Physics and the following courses:

PHYS 325 (3), 326 (3), 327L (1), 328L (1), 425 (3), 426 (3)

Sample Curriculum for the Bachelor of Science in Physics with Astrophysics Option

Semester 1

- 4 Electives
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 15 Total credit hours

Semester 2

- 5 PHYS 221 & 221L
- 3 PHYS 241 (computational)
- 4 MATH 231 (calculus)
- 3 Social Science
- 3 Language
- 18 Total credit hours

Semester 3

- 3 PHYS 241 (computational)
- 4 MATH 231 (calculus)
- 3 Social Science
- 3 Language
- 1 Elective
- 14 Total credit hours

Semester 4

- 5 PHYS 222 & 222L
- 4 PHYS 242 (waves)
- 3 MATH 332 (vector analysis)
- 3 MATH 335 (ordinary differential equations)
- 3 Humanities (Language)
- 18 Total credit hours

Semester 5

- 3 PHYS 321 (mechanics)
- 4 PHYS 325 & 327L (astrophysics)
- 3 PHYS 333 (electricity & magnetism)
- 3 MATH 254 (linear algebra)
- 4 Biology/Earth Science/Engineering with lab
- 17 Total credit hours

Semester 6

- 4 PHYS 326 & 328L (astrophysics)
- 3 PHYS 334 (radiation and optics)
- 1 PHYS 336L (electrical & magnetic measurements lab)
- 3 PHYS 340 (quantum theory)
- 1 PHYS 380 (practicum in problem solving)
- 3 Humanities
- 3 Social Science
- 18 Total credit hours

Semester 7

- 3 PHYS 411 (thermodynamics)
- 3 PHYS 425 (advanced astrophysics)
- 3 PHYS 443 (atomic and nuclear)
- 3 MATH 336 (intro partial differential equations)
- 4 Biology/Earth Science/Engineering with lab
- 16 Total credit hours

Semester 8

- 3 PHYS 426 (advanced astrophysics)
- 2 PHYS 451 (senior lab)
- 3 MATH 382 (probability & statistics)
- 3 ENGL 341 (technical writing)
- 3 Social Science
- 3 Humanities/Social Science
- 17 Total credit hours

Bachelor of Science in Physics with Atmospheric Physics Option

Minimum credit hours required—130

In meeting the General Education Core Curriculum (page 7), physics majors must choose PHYS 221 and 222 and labs. Requirements include the courses listed above for the Bachelor of Science Degree in Physics and the following courses:

PHYS 427 (3), 428 (3), 432 (3), 433 (3)

Note: PHYS 427, 428, and 432 are offered in alternate years. Students may take either of the following two sequences:

1. Junior year: PHYS 427 (fall); PHYS 428 (spring)
Senior year: PHYS 432 (fall); PHYS 433 (spring)
2. Junior year: PHYS 432 (fall)
Senior year: PHYS 427 (fall), PHYS 428, PHYS 433 (spring)

Sample Curriculum for the Bachelor of Science in Physics with Atmospheric Physics Option (Sequence 1)

Semester 1

- 4 Electives
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 15 Total credit hours

Semester 2

- 4 PHYS 121
- 4 MATH 132 (calculus)
- 4 CHEM 122 & 122L (general)
- 3 ENGL 112 (college English)
- 15 Total credit hours

Semester 3

- 5 PHYS 221 & 221L
- 3 PHYS 241 (computational)
- 4 MATH 231 (calculus)
- 3 Social Science
- 3 Language
- 18 Total credit hours

Semester 4

- 5 PHYS 222 & 222L
- 4 PHYS 242 (waves)
- 3 MATH 332 (vector analysis)
- 3 MATH 335 (ordinary differential equations)
- 3 Humanities (Language)
- 18 Total credit hours

Semester 5

- 3 PHYS 321 (mechanics)
- 3 PHYS 427 (atmospheric physics)
- 3 PHYS 333 (electricity and magnetism)
- 3 MATH 254 (linear algebra)
- 4 Biology/Earth Science/Engineering with lab
- 16 Total credit hours

Semester 6

- 3 PHYS 428 (climate physics)
- 3 PHYS 334 (radiation/optics)
- 1 PHYS 336L (electricity and magnetism lab)
- 3 PHYS 340 (quantum)
- 1 PHYS 380 (practicum in problem solving)
- 3 ENGL 341 (technical writing)
- 3 Social Science
- 17 Total credit hours

Semester 7

- 3 PHYS 411 (thermodynamics)
- 3 PHYS 432 (atmospheric remote sensing)
- 3 PHYS 443 (atomic and nuclear)
- 3 MATH 336 (intro partial differential equations)
- 4 Biology/Earth Science/Engineering with lab
- 16 Total credit hours

Semester 8

- 3 PHYS 433 (special atmospheric problems)
- 2 PHYS 451L (senior lab)
- 3 MATH 438 (partial differential equations)
- 3 Humanities/Social Science
- 3 Social Science
- 3 Electives
- 17 Total credit hours

Sample Curriculum for the Bachelor of Science in Physics with Atmospheric Physics Option (Sequence 2)

Semesters 1 through 4 are the same as for Sequence 1

Semester 5

- 3 PHYS 321 (mechanics)
- 3 PHYS 333 (electricity and magnetism)
- 3 MATH 254 (linear algebra)
- 3 PHYS 432 (atmospheric remote sensing)
- 4 Biology/Earth Science/Engineering with lab
- 16 Total credit hours

Semester 6

- 3 PHYS 334 (radiation/optics)
- 1 PHYS 336L (electricity and magnetism lab)
- 3 PHYS 340 (quantum)
- 1 PHYS 380 (practicum in problem solving)
- 3 Humanities
- 3 Social Science
- 3 Electives
- 17 Total credit hours

Semester 7

- 3 PHYS 427 (atmospheric physics))
- 3 PHYS 411 (thermodynamics)
- 3 PHYS 443 (atomic and nuclear)
- 3 MATH 336 (intro partial differential equations)
- 4 Biology/Earth Science/Engineering with lab
- 16 Total credit hours

Semester 8

- 3 PHYS 428 (climate physics)
- 3 PHYS 433 (special atmospheric problems)
- 2 PHYS 451 (senior lab)
- 3 MATH 438 (partial differential equations)
- 3 Humanities/Social Science
- 3 Social Science
- 17 Total credit hours

Bachelor of Science in Physics with Computer Science Option

Minimum credit hours required—131

In meeting the General Education Core Curriculum (page 7), physics majors must choose PHYS 221 and 222. Requirements include the courses listed above for the Bachelor of Science

Degree in Physics and the following courses:

CSE 113 (4), 122 (3), 221 (3)

An additional six (6) hours of CSE courses numbered 300 or higher

Two particularly interesting sequences are:

1. CSE 344 and 451
2. CSE 410 and 411

Sample Curriculum for the Bachelor of Science in Physics with Computer Science Option

Semester 1

- 3 Electives
- 4 MATH 131 (calculus)
- 4 CSE 113 (computer science)
- 3 ENGL 111 (college English)
- 14 Total credit hours

Semester 2

- 4 PHYS 121
- 4 MATH 132 (calculus)
- 4 CSE 122 (algorithms & data structures)
- 3 CHEM 121 & 121L (general)
- 15 Total credit hours

Semester 3

- 5 PHYS 221 & 221L
- 3 PHYS 241 (computational)
- 4 MATH 231 (calculus)
- 3 CSE 221 (system organization)
- 4 CHEM 122 & 122L (general)
- 19 Total credit hours

Semester 4

- 5 PHYS 222 & 222L
- 4 PHYS 242 (waves)
- 3 MATH 332 (vector analysis)
- 3 MATH 335 (ordinary differential equations)
- 3 MATH 352 (basic concepts)
- 18 Total credit hours

Semester 5

- 3 PHYS 321 (mechanics)
- 3 PHYS 333 (electricity & magnetism)
- 3 MATH 254 (linear algebra)
- 3 CS 344 (design and analysis of algorithms)
- 3 ENGL 112 (college english)
- 15 Total credit hours

Semester 6

- 3 PHYS 334 (radiation and optics)
- 1 PHYS 336L (electrical & magnetic measurements lab)
- 3 PHYS 340 (quantum theory)
- 1 PHYS 380 (practicum in problem solving)
- 4 Biology/Earth Science/Engineering with lab
- 3 Humanities (language)
- 15 Total credit hours

Semester 7

- 3 PHYS 411 (thermodynamics)
- 3 PHYS 443 (atomic and nuclear)
- 3 MATH 336 (intro partial differential equations)
- 3 CSE 451 (parallel processing)
- 3 Humanities/Social Science
- 3 Language
- 18 Total credit hours

Semester 8

- 2 PHYS 451 (senior lab)
- 4 Biology/Earth Science/Engineering with lab
- 3 ENGL 341 (technical writing)
- 6 Social Science
- 3 Language
- 18 Total credit hours

See the Physics Department website at www.physics.nmt.edu for sample curricula for a B.S. in Physics with minors in electrical engineering and mathematics.

Minor in Physics

Minimum credit hours required—19

- PHYS 241 (3), 242 (4)
- Three of the following courses: PHYS 321 (3), 333 (3), 334 (3), 340 (3)
- Three (3) additional hours of upper-division physics

Graduate Program

New Mexico Tech faculty primarily have expertise in Astrophysics and Atmospheric Physics. Most graduate students work in one of these areas. We also have research opportunities in cooperation with other departments on campus, in particular Mathematics and Electrical Engineering. Other interdisciplinary programs are also available through research organizations both on (e.g. shock physics at EMRTC) and off campus (Air Force Research Laboratory, Sandia National Laboratory, and Los Alamos National Laboratory).

Astrophysics

Astrophysics research at NMT encompasses planets, exoplanets, stars, the interstellar medium, galaxies, and active galactic nuclei. Specific faculty interests include stellar formation, galactic dynamics and evolution and interstellar chemistry. The Jansky Very Large Array (VLA) and the Very Long Baseline Array (VLBA) radio telescopes, operated by the National Radio Astronomy Observatory (NRAO), are headquartered on campus, and offer unique opportunities for research in radio astronomy. The Magdalena Ridge Observatory (MRO) operates a 2.4-meter optical telescope and is developing an optical interferometer (MROI) that provides both opportunities in optical instrumentation

design as well as scientific research once first light is achieved. Students may pursue dissertation work not only with regular faculty but also with a number of NRAO staff who have adjunct appointments at Tech.

Atmospheric Physics

Atmospheric physicists at Tech study convection and dynamics (on Earth and other solar system planets), lightning, atmospheric electricity, and the middle and upper atmosphere (including ozone and space weather). Langmuir Laboratory for Atmospheric Physics is a facility unique in the world, providing an instrumented mountaintop specializing in lightning research. Langmuir also includes balloon-launch facilities and a capability in compact instrumentation appropriate for remote and airborne deployments. The convection and dynamics group has its own Beowulf cluster, while the upper atmospheric group supports extremely sensitive spectrographs. Students in our graduate program can acquire deep, hands-on experience with custom scientific instrumentation and electronics, computer modeling and automated data analysis and theoretical and mathematical methods of physics.

Master of Science Program

All students are required to pass a preliminary exam (“prelim”) at the MS level. The prelim covers material in physics and mathematics normally included in the undergraduate physics curriculum. The department offers the exam at the beginning of the Fall and Spring semesters. Failure to pass this exam in the time-line established on entry to the program usually results in dis-enrollment from the graduate physics program. See “Preliminary Exam Policy” on the department website for further details.

The Master of Science degree in Physics may be earned with thesis or independent study:

With Thesis:

The student’s course of study and thesis topic must be approved by the student’s advisory committee. A thesis consists of directed research, and a write-up of the research. An oral defense of the thesis is required. The thesis is an archival document published electronically and kept in the NMT Library.

Without Thesis:

The student’s course of study must be approved by the student’s advisory committee. The student’s committee may require additional coursework beyond that listed below. A student who elects to not write a thesis may or may not participate in research, but they typically write a paper on a topic selected with guidance by the advisory committee. Unlike a thesis, this paper is not archived electronically by the NMT Library.

Master of Science in Physics

In addition to the general master's degree requirements, all students enrolled in the Master of Science degree in Physics must satisfy the following course requirements:

All students must complete PHYS 501 (2) and 502 (2) in their first two semesters.

PHYS 509 (3)

PHYS 505 (3) or 521 (3)

6 credit hours chosen from PHYS 508 (3), PHYS 510 (3), PHYS 518 (3)

PHYS 579 (1), Graduate-Faculty seminar, must be taken for the first four semesters.

Master of Science in Physics with Specialty in Instrumentation

In addition to the general master's degree requirements, all students enrolled in the Master of Science degree in Physics with Specialty in Instrumentation must satisfy the following course requirements:

All students must complete PHYS 501 (2) and 502 (2) in their first two semesters.

PHYS 509 (3)

MATH 587 (3)

6 credit hours chosen from PHYS 508 (3), PHYS 510 (3), PHYS 518 (3)

In addition, the student must take an additional 9 credit hours to be approved by their committee. Potential topics include advanced undergraduate or graduate courses in digital or analog electronics, control theory, optics, optical engineering, spectroscopy, NMR, laser physics, shop techniques, materials (metals, ceramics, polymers), explosives, mechanical design, robotics, vacuum and cryogenic techniques. Students are reminded that it is possible to pursue a limited number of credits at other approved higher education institutions, and so this course work might also be pursued as part of an internship.

PHYS 579 (1), Graduate-Faculty seminar, must be taken for the first four semesters.

Five-Year B.S./M.S. in Physics

The student must complete all the requirements for an M.S. in Physics, as outlined in the Program and Course Catalog. The candidate for the program should apply for admission no later than the end of his/her 5th semester of study. The student must have a minimum cumulative GPA of 3.0, and also specifically an average minimum GPA of 3.0 in all physics and mathematics courses to be eligible to apply for the program.

After successful admission to the 5 year program, the student will apply for graduate standing no later than the 7th semester of study, and thus be dually enrolled their senior year. During the 7th semester, the candidate should select an advisory committee and research topic for the M.S. (Students will complete and be awarded the B.S. at the end of the 4th year, and M.S. at the end of the 5th year.) Students may apply Phys 509 to both the B.S. and M.S. degree requirements (see sample curriculum below), however all other courses must be counted toward either the B.S. (and thus completed by the 8th semester) or the M.S. The candidate M.S. student may take the department's preliminary examination as soon as the 8th semester of study, and must pass the examination at the M.S. level by the beginning of the 10th semester. For the M.S. degree, the 6 credit-hours of required electives must be non-Physics courses at the 300-level or above and not explicitly counted toward the B.S. A student may pursue either a M.S. with Thesis (6 credits) or a M.S. with Independent Study (3 credits), normally taken during the 9th and/or 10th semester of study. A student is strongly encouraged to pursue research or take courses to apply toward the M.S. during the summer between the 8th and 9th semesters. After completing the B.S., the student may apply for a graduate teaching or research assistantship (TA or RA).

Sample Curriculum for the Five Year B.S./M.S. (4th and 5th Years)

Semester 7

- 3 PHYS 411 (thermodynamics)
- 3 PHYS 443 (atomic & nuclear)
- 3 PHYS 509 (methods of theoretical physics)^ψ
- 1 PHYS 579 (seminar)**
- 3 MATH course 300 level or above
- 3 Social Science/Humanities
- 16 Total credit hours

Semester 8

- 2 PHYS 451 (senior lab)
- 3 PHYS 508, 510 or 518**
- 3 PHYS 579 (seminar)**
- 3 MATH course 300 level or above
- 6 Electives for B.S.
- 3 Graduate electives for M.S.)**, ^α
- 15 (18^α) Total credit hours

—B.S. Complete—

Summer Semester**

- 3 Graduate electives
- 3 Research
- 6 Total credit hours

*Semester 9***

- 2 PHYS 501 (graduate communications)
- 3 PHYS 505 or 521 (continuum mechanics or advanced dynamics)
- 1 PHYS 579 (seminar)
- 3 PHYS 581, 591, or course work
- 3 Out-of-department elective
- 12 Total credit hours

*Semester 10***

- 2 PHYS 502 (graduate communications)
- 3 PHYS 508, 510 or 518
- 1 PHYS 579 (seminar)
- 3 PHYS 590 or 591 (independent study or thesis)
- 3 Out-of-department or PHYS elective
- 12 Total credit hours

—*M.S. Complete*—

^ψ Dually counted toward B.S. and M.S.

^α Only encouraged if summer residence is not feasible

** Counted toward M.S.

Doctor of Philosophy in Physics Program

Students of exceptional ability as demonstrated in previous courses in physics and mathematics may pursue a program leading to the doctoral degree. Our department offers the following four doctoral paths (with requirements for each specified in the next sections.)

Doctor of Philosophy in Physics with Dissertation in Astrophysics

Doctor of Philosophy in Physics with Dissertation in Atmospheric Physics

Doctor of Philosophy in Physics with Dissertation in Mathematical Physics

Doctor of Philosophy in Physics

Doctoral Programs — General Requirements

All doctoral students are required to pass a preliminary exam (“prelim”) at the Ph.D. level. The prelim covers material in physics and mathematics normally included in the undergraduate physics curriculum. The department offers the exam at the beginning of the Fall and Spring semesters. Although doctoral students take the same prelim as MS students, a higher score is required of them.

Doctoral students must pass the exam at the Ph.D. level by the time-line established on their entry into the program. A student without a Master’s degree in Physics must pass the exam at the MS level within their first year in the Ph.D. program. Failure to pass this exam with the required scores and within the specified time usually results in disenrollment from the Ph.D. physics program. See the “Preliminary Exam Policy” on the department website for further details.

In addition to the general doctoral degree requirements, the following course requirements apply to all curricula:

All students must complete PHYS 501 (2) and 502 (2) in their first two semesters.

PHYS 505 (3), 508 (3), 509 (3), 510 (3), 518 (3), and 521 (3) PHYS 579 (1), Graduate-Faculty seminar, must be taken for the first four semesters.

9 credit hours in mathematics beyond that required of an undergraduate physics major.

Doctor of Philosophy in Physics with Dissertation in Astrophysics

In addition to the degree requirements specified above, students completing their dissertation in astrophysics must also complete:

6 credit hours chosen from PHYS 426 (3), 564 (3), 565 (3), 566 (3). PHYS 426 must be completed unless the student has had equivalent material in previous courses.

6 credit hours chosen from PHYS 425 (3), 562 (3), 563 (3), 567 (3).

Doctor of Philosophy in Physics with Dissertation in Atmospheric Physics

In addition to the degree requirements specified above, students completing their dissertation in atmospheric physics must also complete:

PHYS 427 (3), 428 (3)

An additional 6 credit hours must be taken in areas pertinent to the student’s program. This can be achieved by taking PHYS 527 (3), 532 (3), 533 (3), 535 (3), 536 (3), and/or other courses approved by the student’s advisory committee.

Doctor of Philosophy in Physics with Dissertation in Mathematical Physics

In addition to the degree requirements specified above, students completing their dissertation in mathematical physics must also complete:

MATH 435 (3), 438 (3), 442 (3), 471 (3), 535 (3). These may be used to satisfy the 9 credit hours in mathematics required for all curricula.

An additional 6 credits in mathematics and 6 credits in physics, approved by the student’s advisory committee.

Doctor of Philosophy in Physics

In addition to the degree requirements specified above, (12) credit hours of graduate physics or appropriate related fields, approved by the student’s advisory committee, should be completed in his/her field of specialization.

Graduate Minor in Physics

A student seeking a graduate minor in physics must complete at least 6 hours from the following: PHYS 505, PHYS 508, PHYS 510, PHYS 511, PHYS 518, PHYS 519, or PHYS 521. The remaining physics courses must be graded, at least 300-level or above, and be approved by the minor advisor. A total of 12 credits hours in physics (minimum 6 hours at the 500-level) are required for a minor at the level, and 18 hours (minimum 12 hours at the 500-level) for the doctorate level minor.

Physics Courses:

PHYS 109, Introduction to Physics, 3 cr, 3 cl hrs

Corequisite: MATH 101

This is an introductory, algebra-based course covering kinematics, Newtonian mechanics, conservation principles and thermodynamics. The course is taught in a laboratory setting, with emphasis on hands-on work, the scientific method, and formal laboratory reports. Successful completion of the course will satisfy the PHYS 121 Laboratory requirement.

PHYS 121, General Physics I, 4 cr, 3 cl hrs, 2 recitation hrs

Corequisites: PHYS 121L; MATH 131

Introductory concepts. Mechanics, including Newton's Laws of force, linear and angular momentum, energy, gravitation, heat and thermodynamics, and applications. [NMCCNS PHYS 1215: General Education Area III]

PHYS 121L, General Physics Laboratory I, 1 cr, 3 lab hrs

Corequisite: PHYS 121

Experiments from the subject matter of PHYS 121. [NMCCNS PHYS 1215: General Education Area III]

PHYS 122, General Physics II, 4 cr, 3 cl hrs, 2 recitation hrs

Prerequisite: PHYS 121

Corequisites: MATH 132; PHYS 122L

Continuation of PHYS 121 including electricity and magnetism, optics, and atomic and nuclear phenomena. [NMCCNS PHYS 1225: General Education Area III]

PHYS 122L, General Physics Laboratory II, 1 cr, 3 lab hrs

Corequisite: PHYS 122

Experiments from the subject matter of PHYS 122. [NMCCNS PHYS 1225: General Education Area III]

PHYS 221, Comprehensive Physics I, 4 cr, 3 cl hrs, 2 recitation hrs

Prerequisites: PHYS 121; MATH 131

Corequisite: PHYS 221L

A treatment of physics for science and engineering students from a modern point of view. The subject is logically developed starting with optics and the theory of relativity. Quantum and classical mechanics are then introduced. This course is required for physics majors. [NMCCNS PHYS 1215: General Education Area III]

PHYS 221L, Comprehensive Physics Laboratory I, 1 cr, 2 lab hrs

Corequisite: PHYS 221

Laboratory experiments from the subject matter of PHYS 221. [NMCCNS PHYS 1215: General Education Area III]

PHYS 222, Comprehensive Physics II, 4 cr, 3 cl hrs, 2 recitation hrs

Prerequisites: PHYS 221; MATH 131

Corequisites: PHYS 222L; MATH 132

Continuation of PHYS 221. Attempts to probe successively smaller scales are explored. The four forces of nature; practical applications of gravity and electromagnetism. Dynamics of large numbers of particles are introduced, resulting in applications to the everyday world. This course is required for physics majors. [NMCCNS PHYS 1225: General Education Area III]

PHYS 222L, Comprehensive Physics Laboratory II, 1 cr, 2 lab hrs

Corequisite: PHYS 222

Laboratory experiments from the subject matter of PHYS 222. [NMCCNS PHYS 1225: General Education Area III]

PHYS 241, Computational Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 121 or Corequisite PHYS 221; MATH 132

This course goes into more depth than first-year college physics courses on key classical concepts such as force, acceleration, Newton's Laws, and conservation laws. New mathematics will include numerical solution of differential equations and statistical techniques for experimental scientists. The fundamental physics is reinforced by numerical simulations and calculations that the students write themselves. Along the way, students are taught to program in a scientific computing environment. Students should emerge with a firm grasp of classical mechanics and computational skills.

PHYS 242, Vibrations and Waves, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: PHYS 122 or 221; MATH 231

Vibrations and waves are examined from both theoretical and experimental standpoints. Theory describing simple vibrating systems, including coupled oscillators. Laboratory measurements on electrical analogs of vibrating systems. Wave theory for transverse and longitudinal waves. Experiments using electromagnetic radiation in the visible, microwave, and X-ray regions are used to illustrate the nature of waves.

PHYS 301, Laboratory and Shop Techniques, 1 cr, 1 afternoon per week

Instruction in drill and tool bit sharpening, use of hand tools, drill press, lathe, milling machine, shaper, and sheet metal brake.

PHYS 313, Orbital Mechanics, 3 cr, 3 cl hrs

Prerequisite: PHYS 122 or 222; MATH 332 or MENG 305

This is a first upper-division course covering the Newtonian mechanics of orbits.

Applications include ballistic missiles, satellites, and lunar and interplanetary orbits. Spaceflight is simulated using Kerbal Space Program or similar tools. (Same as AE 313.)

PHYS 321, Intermediate Mechanics, 3 cr, 3 cl hrs

Prerequisites: PHYS 241

Corequisite: MATH 335

An intermediate course in the dynamics and statics of particles and rigid bodies.

Introduction to Lagrangian and Hamiltonian mechanics.

PHYS 325, Astrophysics I: Stars, 3 cr, 3 cl hrs

Prerequisites: PHYS 242

Astrophysics is the application of physics to the universe. This course begins with a review of relevant physics and then applies those concepts to the lives of stars. The subject matter includes stellar atmospheres, stellar interiors, star formation, stellar evolution, variable stars, and compact objects.

PHYS 326, Astrophysics II: Planetary and Extragalactic Systems, 3 cr, 3 cl hrs

Prerequisites: PHYS 325

This course continues the application of physics to the rest of the universe. Our own solar system and its formation and evolution, normal galaxies, active galaxies, the large-scale structure of the universe, and cosmology.

PHYS 327L, 328L, Astronomy Laboratory, 1 cr, 3 lab hrs each semester

Prerequisites: PHYS 122, 122L or PHYS 222, 222L; or consent of instructor

A self-paced introduction to astronomical observing and data reduction. Emphasis on techniques such as the operation of telescopes and their auxiliary equipment, astronomical photography, photometry, spectroscopy, and data handling. Exercises chosen from topics in solar system, stellar, galactic, and extragalactic astronomy.

PHYS 333, Electricity and Magnetism, 3 cr, 3 cl hrs

Prerequisites: PHYS 122 or PHYS 222; PHYS 242; MATH 332

Corequisite: MATH 335

This subject is one of the cornerstones for understanding a huge variety of phenomena — electronic and optical devices, communication by telephone, radio waves, optical fibers, and the behavior of atoms and molecules. It is remarkable that so much insight comes from Maxwell's four equations and the Lorentz force law. This course develops these equations in detail and applies them to a variety of problems. It also helps students develop an understanding of the applications of more advanced mathematics in a physical context.

PHYS 334, Radiation and Optics, 3 cr, 3 cl hrs

Prerequisites: PHYS 333; MATH 335

This course explores the behavior of electromagnetic waves, including optical waves, using Maxwell's equations and the Lorentz force law. Included in the course are the topics of radiation, conservation laws, relativistic and non-relativistic electrodynamics, basic geometrical optics and aberration theory, and specific phenomena such as polarization, diffraction and interference. The class will include demonstrations and discussions of these phenomena and modern optical devices.

PHYS 336L, Electrical and Magnetic Measurements Lab, 1 cr, 3 lab hrs

Prerequisite: PHYS 333

Experiments in electricity and magnetism, emphasizing applications to measurements in physics and geophysics.

PHYS 340, Introduction to Quantum Theory, 3 cr, 3 cl hrs

Prerequisites: PHYS 321; MATH 254, 335, or consent of instructor

Electrons, atoms, and radiation. Wave-particle experiments, introductory quantum mechanics, atomic structure and spectra, the hydrogen atom, exclusion principle, electronic structure of atoms, and diatomic molecules.

PHYS 362, Image Processing, 2 cr, 2 cl hrs

Prerequisite: PHYS 122 or 222

An introduction to image processing and computational physics designed for scientists and engineers. Topics will include properties of imaging devices and systems, image construction, analysis, and display. Data will come from satellites and terrestrial sources. Examples will come from current research whenever possible.

PHYS 380, Practicum in Problem Solving, 1 cr, 2 cl hrs

Prerequisite: PHYS 321, or consent of instructor

Methods of problem solving, including dimensional and scale analysis, rapid estimation, and combining knowledge from various disciplines. Class time will be spent analyzing and solving problems posed by the instructor and students. Students will normally be graded S/U, and sections will be strictly limited in size to facilitate active participation of all students.

PHYS 389, Pilot Course, topic, hrs, and cr to be arranged

PHYS 391, Directed Study, hrs and cr to be arranged

PHYS 408, Cooperative Education

On-the-job training to supplement the academic program. Students alternate periods (usually six months long) of full-time semiprofessional employment in their chosen field with periods of full-time academic study.

PHYS 411, Thermodynamics and Statistical Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 122 or PHYS 222; PHYS 340

Corequisite: MATH 335

A course dealing with the effects of heat and work on gases, liquids, and solids. The equations of state and the first and second laws of thermodynamics are presented with applications to heat engines and chemical processes. An introduction is given to kinetic theory and statistical mechanics.

PHYS 421, Continuum Mechanics, 3 cr, 3 cl hrs

Prerequisites: PHYS 121 or PHYS 221; MATH 332, 335

Offered on demand

Statics and dynamics of fluids and elastic bodies.

PHYS 425, Astrophysics III: Plasma Astrophysics, 3 cr, 3 cl hrs

Prerequisites: PHYS 325, 326, 333

Plasma and fluid physics govern most of the luminous matter in the universe. This course surveys the many aspects of plasma physics, from microphysics (single particle motions, waves and oscillations, collisions) to macrophysics (the fluid description and magnetohydrodynamic effects). Applications will include a wide variety of astrophysical objects, from the earth's magnetosphere and the solar wind, to accretion disks and radio jets.

PHYS 426, Astrophysics IV: High Energy Astrophysics, 3 cr, 3 cl hrs

Prerequisites: PHYS 333 and 425; or consent of instructor

This course continues the application of fluid and plasma physics to astrophysics. Radiation processes and diagnostics, shock physics, high energy plasmas, and cosmic ray acceleration. Many applications will come from our galaxy, including the interstellar medium, star formation, supernovae, black holes, and pulsars. We will go beyond the boundaries of our galaxy to study active galactic nuclei and their connection to galaxy formation.

PHYS 427, Atmospheric Physics, 3 cr, 3 cl hrs

Prerequisites: PHYS 122 or 222; or consent of instructor

Offered alternate years

Covers dry and moist thermodynamics, radiative transfer, some microphysics, and dynamics (including hydrostatic balance, geostrophic balance, and thermal wind equation).

PHYS 428, Climate Physics, 3 cr, 3 cl hrs

Prerequisites: PHYS 427; MATH 332 and 335

Offered alternate years

This course, a continuation of PHYS 427, includes the dynamics needed to understand general circulation (e.g. Rossby waves), also covers basics in climate modeling and observations.

PHYS 432, Atmospheric Remote Sensing, 3 cr, 3 cl hrs

Prerequisite: PHYS 122 or 222

Remote sensing from space and ground-based instruments is a useful technique for monitoring the physical and chemical state of the atmosphere. This course will examine the physics of remote sensing using radio, microwave, infrared, visible, and ultraviolet instruments. Topics will include both active and passive systems for measuring atmospheric temperature, composition, and dynamics.

PHYS 433, Special Problems in Atmospheric Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 331

Offered spring semesters

Project in which student works with a member of the atmospheric physics group on current research. This project is expected to lead to a report, conference presentation, or contribution to a published paper. The student should contact an appropriate faculty member within the first two weeks of the fall semester to organize a project.

PHYS 443, Atomic and Nuclear Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 340

Continuation of PHYS 340. Further topics in atomic and molecular structure. Quantum statistics with applications to degenerate Fermi and Bose Fluids. Radioactivity, elements of nuclear structure, nuclear energy sources. Mesons, hyperons, and resonances.

PHYS 444, Solid-State Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 340 or consent of instructor

Offered on demand

Theory and application of solid-state devices; binding in molecules and crystals; energy bands; electrons in metals; imperfections in solids; electrical, thermal, and magnetic properties of solids; and semiconductor theory.

PHYS 448, Introduction to Particle Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 222 and PHYS 340, or consent of instructor

This course provides an introduction to elementary particles and their interactions, at a level that does not require quantum field theory. Covered topics include particle phenomenology and conservation laws, relativistic kinematics, symmetries, Feynman diagrams, gauge theories, and the Higgs mechanism. Shares lecture with PHYS 548, with additional expectations for graduation credit.

PHYS 449, Astrobiology, 3 cr, 3 cl hrs

Prerequisite: CHEM 121 & 122, PHYS 121 & 122, one other science course and consent of instructor.

An in-depth and interdisciplinary study of astrobiology, including interactions between living and non-living systems at multiple scales: stellar, planetary, meso-, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principles of astrophysics, geosciences, planetary science, chemistry, and biology. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with PHYS 549, with additional expectations for graduate credit. (Same as BIOL 449 and EARTH 449)

PHYS 451, Senior Laboratory, 1 or 2 cr, 3 or 6 lab hrs

Prerequisites: Senior status or consent of instructor

Experiments in atomic, nuclear, and solid-state physics.

PHYS 489, Pilot course, topic, hrs, and cr to be arranged**PHYS 491, Directed Study, hrs and cr to be arranged****PHYS 500, Directed Research, cr to be arranged**

This course may not be used to fulfill graduate degree requirements.

Research under the guidance of a faculty member.

PHYS 501, 502, Introduction to Research and Scientific Communication, 2 cr, 3 lab hrs each semester

This course involves beginning graduate students in a modest project, usually related to ongoing research in the department, and provides a background in scientific communication. The research portion emphasizes independent work by the student, but is supervised by a faculty member. Possible projects include data analysis, software development, theoretical modeling, a literature survey, and design and/or construction of research or teaching equipment. The communication portion incorporates the research topic into several written and oral assignments, including conference abstracts, proposals, oral and poster presentations, and peer-reviewed research papers.

PHYS 505, Advanced Dynamics, 3 cr, 3 cl hrs

Offered Fall 2014 and alternate years

Introduction to classical mechanics: Lagrangian and Hamiltonian formalism, rigid body motion, normal modes. Hamilton-Jacobi Theory, and problems in relativistic mechanics.

PHYS 508, Statistical Mechanics, 3 cr, 3 cl hrs

Offered Spring 2010 and alternate years

Entropy, randomness, the Boltzmann distribution, and the chemical potential. Translational, rotational, vibrational, and electronic contributions to the partition function. Calculation of mean energies, heat capacities, and equilibrium constants. Stability. The influence of wave function symmetry: Bose-Einstein and Fermi-Dirac statistics. The quantum statistical operator. Coherence and the Pauli principle. (Same as CHEM 524)

PHYS 509, Methods of Theoretical Physics, 3 cr, 3 cl hrs

(Note: MATH 535, 536 is Methods of Mathematical Physics)

Prerequisite: MATH 254, 332, and 336 or equivalent, or graduate standing.

Offered Fall semesters

Covers mathematics essential for PHYS 510 and 518, including Dirac delta functions, vector spaces, operators and eigenvalues, Dirac notation, Fourier series and transforms, orthogonal polynomials, complex variables, and tensor notation.

PHYS 510, Electromagnetism, 3 cr, 3 cl hrs

Prerequisite: PHYS 509

Offered Spring and alternate years

Electrostatic and magnetostatic boundary-value problems, electromagnetic radiation generation, wave propagation in materials and at interfaces, polarization characteristics of radiative processes, and the relativistic covariance of electromagnetism will be covered.

PHYS 511, Advanced Electromagnetism, 3 cr, 3 cl hrs

Prerequisite: PHYS 510

Offered on demand

Selected topics taken from advanced electromagnetism: optical fiber propagation, plasma waves and instabilities, scattering of radiation, optical coherence, and other topics based upon interests of the class.

PHYS 518, Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisites: PHYS 505 and 509

Offered Spring 2015 and alternate years

Review of experiments leading to quantum theory: Schroedinger's Equation, applications of simple physical systems, perturbation theory, theory of angular momentum, and Dirac Theory.

PHYS 519, Advanced Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisites: PHYS 518

Offered on demand

Advanced topics in quantum mechanics, including scattering theory, Feynman path integrals, an introduction to quantum field theory, and other topics based upon interests of the class.

PHYS 521, Continuum Mechanics, 3 cr, 3 cl hrs

Offered Fall 2015 and alternate years

Stress, strain, rate of strain, and applications of these ideas in fluid dynamics and elastic body mechanics. Statics of elastic bodies and elastic waves. Navier-Stokes equation, vorticity dynamics, flows at low and high Reynolds number. Examples taken from a broad variety of areas. Co-taught with PHYS 421. Extra work assigned for graduate credit.

PHYS 526, Fluid Dynamics, 3 cr, 3 cl hrs

Offered 2010 and alternate years

Basic equations, potential and viscous flow, scaling. Compressible flow including characteristics and shock waves. Magnetohydrodynamics, including MHD waves, shocks, and confinement. Fluid and MHD instabilities. Turbulence.

PHYS 527, Geophysical Fluid Dynamics, 3 cr, 3 cl hrs

Dynamics of stratified, rotating fluids; governing equations of the ocean and atmosphere, inertia-gravity waves, quasi-geostrophic theory, Rossby waves, instabilities, and jets, diabatic and frictional effects, tropical atmospheric dynamics.

PHYS 532, Atmospheric Remote Sensing, 3 cr, 3 cl hrs

Physics of remote sensing using radio, microwave, infrared, visible, and ultraviolet instruments. Topics will include both passive and active systems for measuring atmospheric temperature, composition, and dynamics. Shares lectures with PHYS 432, but is graded separately and additional graduate-level work is required.

PHYS 533, Advanced Topics in Atmospheric Physics, 1–3 cr, 1–3 cl hrs

Specialized coursework in the student's areas of interest. Advanced topics in the area of atmospheric physics. Selection of topics changes from semester to semester. Current faculty interests can be found at the department web site: www.physics.nmt.edu. This course may be repeated for credit if the material covered in each instance is different.

PHYS 535, Physics of Lightning, 3 cr, 3 cl hrs

Offered Spring 2016 and alternate years

Theory and experimental techniques concerning cloud charging mechanisms. Remote and in-situ sensing of lightning. Lightning phases and properties. Properties of the long spark and leaders in the lab and in the sky. Simple numerical models of cloud charging, lightning initiation, and propagation.

PHYS 536, Atmospheric Convection, 3 cr, 3 cl hrs

Governing equations, turbulence, thermodynamics, and microphysics of moist convection. Models for convection ranging from plumes and thermals through numerical simulations are discussed, as well as interactions of convection with the atmospheric environment.

PHYS 546L, Electrical and Magnetic Measurements Graduate Lab, 1 cr, 3 lab hrs

Prerequisite: Graduate standing or consent of instructor

Experiments in electricity and magnetism, emphasizing applications to measurements in physics and geophysics. Topics include DC and AC circuits, complex impedance, transformers, magnetic hysteresis, transistors, operational amplifiers, superconductivity, and student selected projects. Shares lab with Physics 336L but graduate students will face a higher standard on lab reports and be required to do some additional formal study of electronics. The course is recommended for graduate students lacking practical electronics experience.

PHYS 548, Introduction to Particle Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 222 and PHYS 340, or consent of instructor

This course provides an introduction to elementary particles and their interactions, at a level that does not require quantum field theory. Covered topics include particle phenomenology and conservation laws, relativistic kinematics, symmetries, Feynman diagrams, gauge theories, and the Higgs mechanism. Shares lecture with PHYS 448, with additional expectations for graduation credit.

PHYS 549, Astrobiology, 3 cr, 3 cl hrs

Prerequisites: Graduate standing or consent of instructor.

Offered on demand.

An in-depth and interdisciplinary study of astrobiology, including interactions between living and non-living systems at multiple scales: stellar, planetary, meso, and microscopic. Addresses fundamental questions regarding the origin of life, and the possible extent and distribution of life in the universe. Combines principles of astrophysics, geosciences, planetary science, chemistry, and biology. Innovative interactive exercises and projects working in interdisciplinary groups and individually. Shares lecture with PHYS 449, with additional expectations for graduate credit. (Same as BIOL 549 and GEOL 549)

PHYS 562, Stellar Astrophysics, 3 cr, 3 cl hrs

Prerequisites: PHYS 425, 426 or equivalent or consent of the instructor.

Offered Spring 2015 and alternate years.

This course covers in-depth the physics of stars, their structure and evolution. Topics include energy generation and transport, nucleosynthesis, equations of state, stellar modeling, asteroseismology, and stellar pulsation and rotation — all studied in the context of the evolution of a star. There are detailed discussions and derivations of the various stages in star formation and evolution, and the end states of stars (e.g. white dwarfs, planetary nebulae, black holes). The course stresses current refereed literature and has occasional guest speakers on various topics.

PHYS 563, Extragalactic Astrophysics, 3 cr, 3 cl hrs

Prerequisites: PHYS 425, 426 or equivalent or consent of instructor

Offered Fall 2014 and alternate years

The structure and dynamics of galaxies. Distribution of galaxy types. Potential and orbit theory. Spheroidal galaxies as self-gravitating systems. Instabilities in disk galaxies. Constraints on dark matter and on galaxy formation.

PHYS 564, Relativity and Cosmology, 3 cr, 3 cl hrs

Prerequisites: PHYS 425, 426 or equivalent or consent of instructor

Offered Spring 2013 and alternate years

General relativity with application to cosmology. Basic principles of relativity. Applications to orbits, gravitational radiation, and black holes. Relativistic cosmography and cosmology. The early universe, galaxy formation, and active galaxies.

PHYS 565, Astronomical Techniques, 3 cr, 3 cl hrs

Offered on demand

Optical, IR, X-ray and gamma-ray astronomical telescopes and detectors. Throughput, detector quantum efficiency, the modulation transfer function, noise and estimation error. Photometers and photometric systems, CCD imaging, slit and objective grating spectrometry, Fourier spectroscopy. Astrometry, orbit determination. Computer analysis and astronomical databases. Class work will be augmented by extensive optical observing using local facilities.

PHYS 566, Advanced Radio Astronomy, 3 cr, 3 cl hrs

Offered Fall 2015 and alternate years

The design and operational characteristics of radio telescopes and interferometers. Properties of antennas, telescope optics, feeds, waveguides, receivers, and amplifiers. Spectrometers and spectroscopy. Sensitivity and noise. Amplitude and phase calibration, faint signal detection, astrometry, and mapping. Factors that affect radio data, including instrumental characteristics, atmospheric limitations, and propagation phenomena. The VLA and VLBA and the techniques of radio imaging by aperture synthesis. Hands-on astrophysical exercises to be solved by imaging.

PHYS 567, Advanced Topics in Astrophysics, 2–3 cr, 2–3 cl hrs

Offered on demand

A one-semester tutorial may be selected from any one of the following: our solar system, comets, solar and stellar activity, galactic structure and kinematics, active galaxies and quasars, astrophysical plasmas, accretion disks, black holes, stellar spectroscopy, stellar photometry and astrometry.

PHYS 571, Advanced Topics in Physics, 3 cr, 3 cl hrs

Offered on demand

Study of a special topic not otherwise treated, normally one related to a field of research interest at NMT.

PHYS 579, Graduate-Faculty Seminar, 1 cr, 1 cl hr

Offered every semester

A seminar in which current research topics are discussed by faculty, students, and outside speakers. Graded S/U, where satisfactory performance consists of regular attendance and participation. Credit earned may not be applied towards the 30 credits required for the M.S. degree.

PHYS 581, Directed Study, cr to be arranged

Study under the guidance of a member of the graduate faculty. In general, subject matter will supplement that available in other graduate course offerings.

PHYS 590, Independent Study, cr to be arranged**PHYS 591, Thesis (master's program), cr to be arranged****PHYS 595, Dissertation (doctoral degree program), cr to be arranged**

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Physics Faculty Research Interests

Arendt—Physics in Strong Magnetic Fields, Neutron Star Magnetospheres, Mathematical Physics
 Avramidi—Mathematical Physics, Analysis on Manifolds, Quantum Field Theory
 Buscher—Optical/IR Interferometry, Atmospheric Seeing Measurement, Adaptive Optics, Early and Late Stages of Stellar Evolution
 Creech-Eakman—Stellar Astrophysics, Mass-loss, Optical/IR Interferometry, IR Instrumentation, Exoplanets
 Eack—Production of Energetic Particles and Gamma Rays in Thunderstorms
 Eilek—Plasma Astrophysics, Quasars, Radio Galaxies, Pulsars
 Elvis—Quasars and Active Galactic Nuclei, X-ray Astronomy
 Fuchs—Atmospheric Dynamics
 Goss—Radio Astronomy, Interstellar Medium
 Haniff—Spatial Interferometry at Optical and Near-Infrared Wavelengths, Atmospheric Turbulence, Imaging Theory, Evolved Stars
 Hankins—Radio Astronomy of Pulsars, Instrumentation, Signal Processing
 Hofner—Star Formation, Interstellar Medium, X-ray Astronomy, Extragalactic Interstellar
 Klinglesmith—Asteroids, Robotic Telescope Operations
 Krehbiel—Lightning studies; radar meteorology; thunderstorm electrification
 LeFebre—Statistical Physics and Thermodynamics
 Lopez Carrillo—Doppler Radar and Data Analysis, Tropical Dynamics

Manney—Atmospheric Science, Stratospheric Dynamics/Transport, Stratospheric Polar Processes and Ozone Loss
 Meason—Nuclear Physics, Nuclear & Space Radiation Effects, Electromagnetic Radiation Effects & Directed Energy
 Meier—Radio/Submm Studies of Galaxies, Astrochemistry
 Meyers—Cosmology, Extragalactic Radio Astronomy, Interferometric Imaging Algorithms
 Minschwaner—Radiative Transfer and Climate, Physics of the Middle and Upper Atmosphere
 Morales-Juberias—Outer Planets Observations and Atmospheric Dynamics
 Raymond—Geophysical Fluid Dynamics, Cloud Physics, Clouds and Climate
 Rison—Atmospheric Electricity, Radar Meteorology, Instrumentation
 Romero—Energetic Materials, Shock Phenomena, High Energy Physics
 Rupen—Gas and Dust in Galaxies, Radio Transients
 Schery—Environmental Radioactivity
 Sessions—Field Theoretic Approaches to Atmospheric Physics
 Sonnenfeld—Charge Transport by lightning, Embedded systems and instrumentation, Tribocharging of ice
 Teare—Experimental Adaptive Optics, Radiation Effects and Directed Energy
 Thomas—Atmospheric Physics, Instrumentation
 Westpfahl—Dynamics of Spiral and Dwarf Galaxies
 Winn—Atmospheric physics; electrical discharges in gases; instrumentation
 Young—Star Formation and the Interstellar Medium, Dwarf and Elliptical Galaxies

Preprofessional Programs

Specific requirements for admission to professional schools vary. With the help of an advisor, each preprofessional student should plan a course of study that will meet the specific entrance requirements of the school in which the student is interested. The following statements outline the usual requirements for programs which may be completed with course offerings available at Tech. Preprofessional students who complete the requirements for the Bachelor of Science degree in Basic Sciences with appropriate selection of electives will qualify for admission to most professional schools.

Preprofessional training in the biological and medical allied sciences consists of a thorough background in basic sciences. Hence, the first two years will be essentially the same for all specialties. Courses during the first two years should include ENGL (two semesters); BIOL 111, 112, 331, 333; CHEM 121, 122, 333, 334; MATH 131, 132; PHYS 121, 122; PSY 121; and social science (two semesters).

Predental, Prephysical Therapy, and Preoptometry Programs

Most accredited schools of these specialties require a minimum of two years of college work. However, most schools give preference to students with three or four years of preparation. Courses should include those listed above for the first two years.

Premedical Program

Students interested in preparing for admission to medical school should meet frequently with their advisors, beginning with their first semester at New Mexico Tech. Accredited medical schools require a minimum of three years of college work, with a minimum grade-point average of 3.0. However, most students complete a bachelor's degree before entering medical school.

Students are advised to consult the requirements of individual medical schools in choosing coursework. Upper division courses in New Mexico Tech's curriculum that may aid in medical school preparation include BIOL 311, 341, 351, 352, 355, and 437; CHEM 311, 331, 332, 441, and 442. Most premedical students major in biology, however, any bachelor's degree is acceptable. Premedical students should be aware that the Medical College Admissions Test is required for admission to medical school.

Premedical Technology Program

Students interested in preparing for admission to veterinary school should meet frequently with their advisors, beginning with their first semester at New Mexico Tech. Schools of medical technology require a minimum of three years of undergraduate study; however, the degreed student

has a distinct advantage because of the extra year of preprofessional training. Recommended courses in addition to those described above for the first two years include BIOL 311, 341, 351, 355; and CHEM 311.

Preveterinary Medicine Program

A minimum of two years of acceptable college work is required for admission to a college of veterinary medicine. However, most students complete a bachelor's degree before entering veterinary school. Courses to be included in a two-year program should be those described above. Students should add as many additional courses from those listed under the premedical program. A four-year program should include the remaining biology and chemistry courses of the premedical program and be planned to meet the degree requirements for the Bachelor of Science degree in biology, chemistry, or basic sciences.

Prenursing Program

An increasing number of schools of nursing now require one year of general liberal arts courses for admission. Courses recommended for such nursing curricula are English (two semesters); BIOL 111, 112, 341; general chemistry; general psychology; and general physics (one semester each).

Prepharmacy Program

Most accredited colleges of pharmacy offer a five-year program, including prepharmacy training, leading to a Bachelor of Science in Pharmacy degree. All such colleges of pharmacy require at least one year of prepharmacy study and some colleges will accept two years. The University of New Mexico has an accredited College of Pharmacy which accepts one year of prepharmacy study. Recommended courses in the prepharmacy curriculum are ENGL 111 and 112; CHEM 121 and 122; BIOL 111; and MATH 131 (MATH 132 recommended).

Prelaw Program

The usual requirement for admission to an accredited school of law is a baccalaureate degree from an accredited college.

Law schools often look for successful completion of English and writing courses as evidence of writing ability, and successful completion of mathematics and science courses as evidence of logical reasoning ability.

Many Tech degrees are suitable background for the field of patent law. Students interested in patent law should consult with an advisor early in their college career, to ensure they take appropriate courses. Contact Academic Affairs for further information and academic advising.

Psychology

Associate Professor Samuels (Chair of the Department)

Assistant Professors Elliott, Thompson

Adjunct Professor Thomas

Emeritus Professors Etscorn, Holson

Degree Offered: B.S. in Psychology

The program in psychology is designed to provide students with a scientific foundation in the methods and basic data in psychology and neuroscience and to prepare students for further work in all specializations within the field. Students acquire the fundamentals of learning and memory, reasoning and problem solving, perception, emotion, attention, thought, language and communication, the development of all these processes and their pathology. In addition, we apply psychology to other fields and teach techniques for measuring and studying psychological variables. Students conduct laboratory experiments on the psychological and physiological bases of behavior. The department has a modern animal care facility for laboratory classes and research. There are many opportunities for independent research.

Undergraduate Program

Bachelor of Science in Psychology

Minimum credit hours required — 130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- PSY 121 (3); 205 (4), 472 (1)
- Two courses (with associated labs) chosen from among PSY 301 (4), 305 (4), 309 (4)
- 15 additional credit hours in psychology
- BIOL 111 (4), 112 (4), and at least six (6) upper-division credits in Biology, exclusive of BIOL 471 or 472
- MATH 283 (3) or 483 (3)
- At least four (4) additional credit hours beyond the General Education Core Curriculum and above the Psychology requirements selected from among Biology, Computer Science, Chemistry, Mathematics, and Physics.
- Electives to complete 130 credit hours

Students intending to major in psychology should complete PSY 121 and 205 by the end of their sophomore year. They are advised to complete the biology and mathematics requirements as early as possible since material from these courses will be used in upper-division courses.

Sample Curriculum for the Bachelor of Science in Psychology

Semester 1

- 3 PSY 121 (general)
- 3 ENGL 111 (college English)
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 1 Elective
- 15 Total credit hours

Semester 2

- 4 PSY 205 (experimental)
- 3 ENGL 112 (college English)
- 4 MATH 132 (calculus)
- 4 CHEM 122 & 122L (general)
- 15 Total credit hours

Semester 3

- 3 PSY 212 (drugs and behavior)
- 3 PSY 323 (developmental)
- 5 PHYS 121 & 121L (general)
- 4 BIOL 111 (general)
- 3 MUS 105 (fundamentals)
- 18 Total credit hours

Semester 4

- 3 PSY 209 (social)
- 3 MATH 283 (statistics)
- 5 PHYS 122 & 122L (general)
- 4 BIOL 112 (general)
- 3 Elective
- 18 Total credit hours

Semester 5

- 4 PSY 301 (perception)
- 3 HIST 151 (world history I)
- 3 BIOL 331 (cell biology)
- 3 PHIL 231 (introduction)
- 4 CSE 113 (introduction)
- 17 Total credit hours

Semester 6

- 4 PSY 305 (cognitive psychology)
- 3 HIST 152 (world history II)
- 4 BIOL 351 (physiology)
- 3 ENGL 341 (technical writing)
- 3 Elective
- 17 Total credit hours

Semester 7

- 4 PSY 309 (behavioral neuroscience)
- 3 PSY 330 (abnormal)
- 9 Electives
- 16 Total credit hours

Semester 8

- 1 PSY 472 (seminar)
- 3 PSY 362 (animal behavior)
- 11 Electives
- 15 Total credit hours

Minor in Psychology

Minimum credit hours required—20

The following courses are required:

- PSY 121 (3), 205 (4)
- PSY 301 (4) or PSY 305 (4) or PSY 309 (4)
- Additional nine (9) credit hours in psychology

Students may also do an option in Cognitive Neuroscience as part of the Biomedical Sciences Program (see page 21).

Psychology Courses

The following courses may be used to fulfill Area 4: Social Sciences portion of the General Education Core Curriculum, page 7.

PSY 121, General Psychology, 3 cr, 3 cl hrs

The study of behavior. Includes perception, motivation, learning, personality, social processes, and physiological processes. [NMCCNS PSYC 1113: General Education Area IV]

PSY 131, Science and Pseudoscience, 3 cr, 3 cl hrs

This course examines methods for determining whether given claims are science or pseudoscience. Several controversial topics will be explored, with emphasis on coming to objective decisions about such claims. Topics include logical fallacies, the Scientific Method, creationism, global warming and climate change, hidden codes in the Bible, Relativity theory, 9/11 Truth conspiracy claims, Dark Matter, UFO sightings, Perpetual Motion Devices, Quantum Mechanics, Quack medical claims and more.

PSY 205, Experimental Psychology, 4 cr, 3 cl hrs, 2 lab hrs

Prerequisite: PSY 121; a lab usage fee is charged

Basic concepts and research methodology in the study of behavior; emphasis on experimental design, control, and laboratory methods.

PSY 209, Social Psychology, 3 cr, 3 cl hrs

Prerequisite: PSY 121

Study of the manner by which the behavior of one individual is influenced by the behavior and other characteristics of others. Includes social perception and cognition, attitudes, prejudice, interpersonal attraction, cooperation, group behavior, and aggression.

PSY 212, Drugs and Behavior, 3 cr, 3 cl hrs

Prerequisite: PSY 121

An overview of the design and interpretation of psychopharmacological research; emphasis on self-administered drugs as well as addictions and treatment.

PSY 301, Perception, 4 cr, 3 cl hrs, 2 lab hrs

Prerequisites: PSY 205; a lab usage fee is charged

Experimental and theoretical study of sensory mechanisms and perceptual processes.

PSY 305, Cognitive Psychology, 4 cr, 3 cl hrs, 2 lab hrs

Prerequisites: Psychology 205 passed with a C- or better; a lab usage fee is charged.

A study of research findings, major issues and theories of mental processes. Topics include attention, learning, memory, imagery, concept formation, language and its development, thinking, problem solving and decision making. The laboratory is designed to give students the opportunity to explore the experimental bases of cognitive processes.

PSY 309, Behavioral Neuroscience, 4 cr, 3 cl hrs, 2 lab hrs

Prerequisites: Psychology 205 passed with a C- or better; Biology 111, 112; a lab usage fee is charged

Study of the neural and other physiological bases of behavior. Functional neuroanatomy of sensory and motor systems, motivation and drives, learning and emotion. Clinical correlates of neurological abnormalities are emphasized. Laboratory concentrates on the neuroanatomy of sheep, rat and human brain.

PSY 311, Tests and Measurements, 3 cr, 3 cl hrs

Prerequisite: PSY 121

Design, administration, interpretation, and evaluation of psychological and educational tests. Includes measurement theory as well as practical techniques.

PSY 312, Psychopharmacology, 3 cr, 3 cl hrs

Prerequisites: PSY 212; BIOL 111, 112

Behavioral and pharmacological techniques for the study of drugs acting on the nervous system. Topics include sites of drug action, CNS toxicity, psychotherapeutics, and experimental designs employed in psychopharmacological research.

PSY 323, Psychology of Child and Adolescent Development, 3 cr, 3 cl hrs

Prerequisite: PSY 121

The development of human behavior from conception to adolescence. Includes cognitive, social, behavioral, and physical development.

PSY 323L, Psychology of Child and Adolescent Development Lab, 1 cr, 2 cl hrs

Corequisite: PSY 323 and consent of instructor

This course is intended to help students understand, through firsthand observation, theories and ideas taught in Child and Adolescent Development (PSY 323). The class will focus on the biological, perceptual, cognitive, behavioral, linguistic and socialemotional development of preschoolers at the NMT Children's Center.

PSY 324, Psychology of Adult Development and Aging, 3 cr, 3 cl hrs

Prerequisite: PSY 121

The development of human behavior from early adulthood to old age. Cognitive, social, behavioral, emotional, and physical development. Life tasks, careers, physical and emotional health, leisure, dying, and death.

PSY 330, Abnormal Psychology, 3 cr, 3 cl hrs

Prerequisite: PSY 121

An introduction to psychopathology. Includes the etiology, diagnosis, treatment, and prognosis of behavioral disorders.

PSY 335, Human Factors in Science & Engineering, 3 cr, 3 cl hrs

Prerequisite: PSY 121 or consent of instructor

This course explores how human capabilities and limitations influence decision making and performance and how scientists and engineers can use knowledge of these factors to design workspaces and devices to maximize human capabilities and minimize human limitations. The class focuses on how cognitive processes and biases in perception, attention, memory and problem solving influence performance. Examples of "human error" and ways in which error can be averted will be studied. Comparisons will be made between human and artificial intelligence.

PSY 350, Psychobiology of Sex, 3 cr, 3 cl hrs

Prerequisite: PSY 121 or consent of instructor

Sexual reproduction in a broad evolutionary context. Topics include sexual and asexual reproduction, sexual selection, the endocrinology of mammalian reproduction, development of the reproductive system and sexually differentiated behaviors, sex differences in the brain, and human behavioral sex differences.

PSY 362, Animal Behavior, 3 cr, 3 cl hrs

Prerequisites: PSY 121 or consent of instructor

General overview of ethological and physiological approaches to the study of animal behavior. (Same as BIOL 362)

PSY 376, Mass Violence and Aggression, 3 cr, 3 cl hrs

Prerequisite: Upper-division standing or consent of the instructor

This course examines the nature and dynamics of mass violence and aggression, and their impact on politics and societies. Through lectures and readings the students explore and compare political, sociological and psychological dimensions of genocides, state terror, and ethnic cleansing. (Same as HIST 376)

PSY 389, Special Topics in Psychology, cr and hrs to be arranged

PSY 391, Directed Study, hrs and cr to be arranged

Prerequisite: Upper-division standing in psychology

Supervised individual work in psychology. May be repeated for more than one semester's work.

PSY 400, History of Psychology, 3 cr, 3 cl hrs

Prerequisite: Nine hours in psychology

Study of central questions and concepts of psychology from their origins in classical philosophy and medicine to modern times.

PSY 472, Senior Seminar, 1 cr, 1 cl hr each semester

Prerequisite: Upper-division standing or consent of instructor

Review and discussion of current research in psychology.

PSY 495, Biomedical Senior Thesis I, 3 cr

For Biomedical Science majors. Mentored, problem-oriented biomedical research under the direction of a faculty member. Students should consult with their academic advisor and with various Psychology faculty to identify a Thesis advisor. Near the end of the semester, students will give a formal research presentation.

PSY 496, Biomedical Senior Thesis II, 3 cr

For Biomedical Science majors. Continuation of BIOL 495. Students are required to write a paper on the research project and to give an oral presentation.

Faculty Research Interests

Elliott—Neuroethology, Systems Neuroscience, Language, Music Cognition, Auditory Perception
 Samuels—Cognitive Development, Reasoning and Problem Solving, Memory, Brain Injury and Rehabilitation
 Thompson—Animal behavior, Neuroscience, Eye Disease, Gene and Cell Replacement Therapy

Master of Science for Teachers (MST)

Interdepartmental Program within the Department of Psychology and Education (Mark Samuels, Department Chair; George Becker, Coordinator)

Advisory Committee: Jeff Altig (Chemistry), William Chávez (Mineral Engineering), Steve Simpson (Communication, Liberal Arts, and Social Sciences), Dave Westpfahl (Physics), Bruce Harrison (Earth and Environmental Science), Dongwan Shin (Computer Science), Warren Ostergren (Vice President of Academic Affairs), Rebecca Reiss (Biology), Anwar Hossain (Mathematics); *Ex-Officio:* Associate Vice President of Academic Affairs, Graduate Dean, Dean of Arts and Sciences, Dean of Engineering, Director of the Academic Center for Technology, Vice President of Student and University Relations, Director of Professional Development, Registrar.

Adjunct Faculty: Ray Collins, Lynn Deming, Dee Friesen, Rob Hepler, Dan Klinglesmith, Lynne Kurilovitch, Eileen Ryan, Elisabeth Stone, Dave Thomas, and Don Wolberg

Degree Offered: Master of Science for Teachers

Program Description

The MST program is designed to provide graduate-level classroom and laboratory instruction for teachers of science, mathematics, engineering, and/or technology. The emphasis of the courses is on content, rather than pedagogy. MST students are encouraged to develop laboratory exercises, demonstrations, and teaching methods from the course content and apply these as projects in their own classrooms during the academic year. Courses for the participants are offered in a variety of disciplines and are taught by New Mexico Tech faculty. Classes build on fundamental principles and offer new concepts and novel teaching methods. Courses are offered throughout the year via distance instruction and as live courses on the New Mexico Tech campus and around the state.

Program Prerequisites

An individual with at least one year of teaching experience may apply for admittance into the MST Program. The Program encourages individuals to hold a valid teaching certificate when appropriate.

Transfer Credit Policy

A maximum of 12 credit hours of course work with grade B or better, earned at another accredited institution, may be approved by the student's advisory committee for transfer to the MST program. To be approved, credits must not have been used to satisfy the requirements for a previous degree. Transfer credits can include upper-division undergraduate or graduate credit in science, mathematics, engineering, and/or technology. Transferred credits may include up to six credit hours of professional education courses in areas generally appropriate to this program. Requests for evaluation of transfer credit hours must be made in writing to the program coordinator and must include the transfer credit form and official transcripts.

Application for Admission

Application forms may be obtained from the internet at www.nmt.edu/~grad/. Printed forms or more information can be requested by e-mail from graduate@nmt.edu or by mail from:

Master of Science for Teachers
Graduate Office
801 Leroy Place, New Mexico Tech,
Socorro, NM 87801

MST Fellowships

The MST Office maintains a list of available fellowships.

Endorsement Policy

Information regarding certification endorsements may be obtained from the New Mexico Public Education Department, Santa Fe, New Mexico.

Placement Exams

MST students may take placement exams for ST: 523, 524, 525, 526, or 550. Upon successful completion of the exam(s), this requisite for the program will be waived and the student will not be required to take the course(s). The exams consist of questions covering basic concepts of science and mathematics.

Use of Tech Facilities

If an MST student is utilizing New Mexico Tech facilities or faculty (i.e., computer center, advisor, or graduate committee), the student must be registered for at least one Tech upper-division or graduate course.

Thesis or Independent Study Requirement

The candidate for the MST degree must select either a thesis or a non-thesis program under the guidance of the student's advisor and advisory committee. The thesis program involves the preparation of a thesis through experimental, theoretical, or applied research (ST 591), under the supervision of a faculty member. The candidate must satisfy the thesis requirements of the department of his/her advisor. Six credit hours will be allowed for the thesis. The Independent Study (IS) provides the candidate with an opportunity to engage in a plan of study under the supervision of NMT Faculty to (a) explore in more depth or detail an area to which the student has been introduced in previous courses or in the field of science-based education and (b) contribute to the knowledge content and/or application of the knowledge content of the selected area. An IS is intended to be a project initiated by the student and designed in conjunction with his/her advisory committee. Three credit hours will be allowed for the IS (ST 590).

Graduate Advisory Committee

Each MST student will be assigned a temporary advisor at the time of first registration. The student will select an advisor and an advisory committee by the completion of 12 credits or within one year of first enrollment (whichever comes first). The student's academic advisor must be a regular faculty member of the Institute. The advisory committee consists of at least the academic advisor and two other members with regular faculty members not being a minority. The academic advisor serves as chair of the advisory committee. The Psychology and Education Chair and the Graduate Dean must approve the advisor and members of the advisory committee. The student should have contact with his/her advisory committee at least once a year.

Course Program

Courses to be used towards each of the graduate degrees at New Mexico Tech must meet with the prior approval of the student's advisory committee. These courses constitute the student's Course Program. The approved Course Program must be on file in the Graduate Office for full-time students no later than the end of the second semester of residency. Part-time and distance education students must formalize their course program by the time they complete 12 credits. The course program is reported on the committee report form, available online and from the Graduate Office.

Program Requirements

All incoming MST students must demonstrate competence in science and mathematics by either:

1. Completing the introductory courses:
 - ST 523, Survey of Biology (1)
 - ST 524, Survey of Chemistry (1)
 - ST 525, Survey of Geology (1)
 - ST 526, Survey of Physics (1)
 - ST 550, Mathematics for Teachers (2)

Credits are awarded for these courses but these credits DO NOT count towards the 30 credits needed for a MST Degree.

2. Passing the appropriate placement exams (see above). No credits are awarded for passing a placement exam. These courses or the appropriate placement exams are prerequisites for most other ST courses.

Master of Science for Teacher students must take the following core of 21 credit hours that will give breadth and depth to the program:

1. All incoming students must take two technical communication courses and a computer literacy course.
 - ST 529, Research and Documentation (2)
 - ST 530, Technical Communication for Teachers (2)
 - ST 556, Computers and Science Teaching (1)
2. For comprehensiveness, MST students must take two credits in each of the following distribution areas, for a total of twelve credit hours:
 - Math (2)
 - Physics (2)
 - Chemistry (2)
 - Geology (2)
 - Biology (2)
 - Engineering/Computer Science/Economics (2)
3. For depth, MST students must take an additional six credit hours within one of the above distribution areas of the student's choice.

In addition to the core requirements above, MST students must complete:

- ST 590, Independent Study (3), or ST 591, Thesis (6)
- Additional courses to complete 30 credit hours. These courses may be chosen from MST courses or other Tech courses numbered 300 or above.

MST Courses:

All MST courses that satisfy a distribution area requirement have at least one survey course as a prerequisite. MST courses that do not apply to a distribution area require competence in basic courses in subject matter area or consent of instructor.

MST courses may not be used to fulfill the requirements of any other undergraduate or graduate degree offered by New Mexico Tech without prior approval by the chair of the department offering the degree.

Students may receive an additional credit of directed study for each course with the submission of an accepted project and paper to the professor of the respective course.

Departmental Waiver of Prerequisites and/or Distribution Area Requirement:

The MST Department Chair and the Department Chair (or his/her designee) representing a distribution area on the MST Advisory Committee must approve a request to waive a prerequisite or distribution area requirement. This request is submitted by the student and must be recommended by the advisor and have the consent of the instructor before consideration.

ST 501 Special Topics

These courses are offered on a request basis:
 Charles Darwin, "The Origin of Species", and Evolution,
 Vertebrate Paleontology,
 Educational Testing,
 Materials Science and Nanomaterials Workshop,
 Growth of the North American Continent,
 Timescapes: The Field Course,
 Computer Basics and MS Office

ST 502D Archaeology for Teachers, 2cr

Prerequisites: ST 525/525D or departmental waiver

A general introduction to the study of the past through material remains and the relationship of archaeology to the sciences. Four major topics are covered: archaeological field and lab method and theory; human evolution; the basic structure of world prehistory; archaeological careers and application of archaeology in the public sphere. Assignments include papers, archaeological analysis problems and classroom lesson plans.

ST 503D Ancestor's Tale, 2cr

Prerequisites: ST 523/523D and ST 525/525D or departmental waiver

Evolution is a theory, a process and a narrative of biological and geological science that elucidates the history of life and its amazing diversity and abundance on Earth. *The Ancestor's Tale* is a course that takes its name from the book (used as the text), written by noted evolutionary biologist Richard Dawkins, and is at once metaphor and narrative of life's journey through almost 4 billion years. The journey of these evolutionary pilgrims begins now, in the present, with our own species *Homo sapiens*, and moves ever deeper back through the evolutionary branchings of organisms in time. The course investigates the unity of all life on Earth through all of time.

ST 505/505D, Human Evolution, 2 cr

Prerequisites: ST 523/523D or departmental waiver

We live on a planet populated by several billion members of a single species, *Homo sapiens*, different from all other species by a unique set of characters and behaviors not seen in any other animal species. This course is concerned with the origin and evolution of who we are and how we got here. The course will trace the origin of the great group to which we belong, the Primates, as well as our distant and not too distant cousins. We will review those traits that make us Primates, along with such interesting animals as the lemurs of Madagascar, the Old World Monkeys, and the Great Apes of Africa.

ST 506D, Dinosaurs and Their World, 2 cr

Prerequisites: ST 523/523D and ST 525/525D; or departmental waiver

This course means to do what its title advertises. Together, we will go on an adventure to look at dinosaurs and their world, a world at once with similarities to our own, and many differences. We will explore a world about which we know a great deal, but also a world that still has many more unanswered questions. We will take a journey back through so much time that the reality of time's distance is reduced to numbers without a sense of the actual enormity of the journey. And yet even that journey is but a small fraction of a still greater timescale of our planet and the universe.

ST 508D Worms, Bugs, and Shells, 2cr

Prerequisite: ST 523/523D or departmental waiver

This course provides an introduction to the major groups of living invertebrate animals. The vast majority of living organisms are animals and fewer than 5% of these are animals with backbones; the majority of the rest are invertebrates, the "worms, bugs and shells" of this course. This course will acquaint students with the main ideas about the classification, anatomy, evolutionary relationships, ecology, behavior, geographical distribution and other aspects of the natural history of the major groups of living invertebrates. Special emphasis will be placed on species found in New Mexico and the Southwest. Technical terminology will be kept to a minimum and the primary focus will be on big ideas.

ST 509D Human Genetics, 2cr

Prerequisites: ST 523/523D and ST550/550BD, or departmental waiver

Human genetics covers the basic principles of transmission and molecular genetics and the application of genetics to human health and reproduction. Lecture topics include forensic DNA analysis, genetic testing for diseases, cancer pre-disposition, *in vitro* fertilization, pre-implantation genetics, evolutionary medicine, and epigenetics. Bioethical issues raised by the development of new genetic tests, including whole-genome sequencing are considered. Participants are required to develop educational modules that can be used in their classes

ST 510/510D Vertebrate Zoology: An Introduction to Animals with Backbones, 2cr

Prerequisites: ST 523/523D or departmental waiver

Vertebrate Zoology provides an introduction to the major groups of living vertebrate animals: fishes, amphibians, reptiles, birds and mammals. Vertebrates comprise a small fraction of all the animals that now exist on Earth, but are the most familiar and attract the most interest, in part because we ourselves are vertebrates. Vertebrates are diverse and abundant, although an increasing number of species are endangered. This course includes the classification, anatomy, evolutionary relationships, ecology, behavior, geographical distribution and other aspects of the natural history of the world's living vertebrates. Special emphasis will be placed on species found in New Mexico and issues of threatened and endangered species, habitat destruction and protection.

ST 513, Molecular Biology Laboratory for Teachers, 2 cr

Prerequisites: ST 523/523D and ST 550/550BD; or departmental waiver

An introduction to the techniques used in molecular biology, including spectrophotometry, electrophoresis, gel filtration, chromatography, hydrolysis, and the analysis of biological polymers.

ST 517, Environmental Studies, 2 cr

Prerequisites: ST 523/523D and ST 550/550BD; or departmental waiver

This course is a study of the interrelationships of organisms with their physical and chemical environment including the biological interactions among populations, communities, ecosystems, and pollutants.

ST 518D Water as a Resource, 2cr

Prerequisites: ST 523/523D and ST 524/524D: or departmental waiver

This asynchronous web course covers one of our most precious resources in New Mexico and beyond. This course covers interesting and timely topics such as drinking water quality and supplies, water-generated energy, water conservation, desalination, ocean currents, weather patterns, water reservoirs, the hydrologic cycle, climate change, and drought, in the same flexible online format as Renewable Energy ST577d. Students view course material in weekly modules, participate in online discussions, complete two projects, and view virtual field trips. The web format allows you to view the course material whenever you want to during that module week. The scope of this course encompasses both local and global water issues and politics plus the biology and chemistry of water systems and supplies. The goal is to give a good understanding of the way water systems work and how they are connected to the other Earth systems, and to prepare students to teach water resources in their classrooms.

ST 519, Modern Genetics, 2 cr

Prerequisites: ST 523/523D and ST 550/550BD and ST 509 (recommended); or departmental waiver

This lab course is an introduction to techniques used to study Mendelian and molecular genetics, including forensic DNA.

ST 523/523D, Survey of Biology, 1 cr

A survey of life functions at the cellular level including the structure of organic molecules, membrane structure and function, energy metabolism, cellular reproduction, and gene action. Also includes an introduction to evolution and phylogenetic survey of the kingdoms of life.

ST 524/524D, Survey of Chemistry, 1 cr

This course is an introduction to basic chemical terminology and nomenclature, modern atomic and molecular theory, periodicities of chemical behavior, and the physical characteristics and isotopic stability of the elements. The student will learn how to read and write properly balanced chemical equations, make meaningful predictions based on stoichiometric relationships, identify and quantify the participants in electron and proton transfer reactions and establish a foundation for pursuing more advanced studies in the chemical, physical, material, life, earth and environmental sciences.

ST 525, Survey of Geology, 1 cr

This course covers the fundamentals of geosciences, including field-based training in how and why geology “works.” Mandatory field trips will introduce participants to the essentials of the study of Earth materials, with classroom sessions discussing the origin of the Earth, its landforms, and materials.

ST 526, Survey of Physics, 1 cr

Explore Newton’s three Laws of Motion in this laboratory course. Hands-on, class time experiments are supplemented with assigned readings. This course is not mathematically intensive.

ST 529/529D, Research and Documentation, 2 cr

Prerequisites: None

This course covers the various kinds of research (both primary and secondary) and documentation, particularly in the fields of science, including gathering and analyzing data, writing (literature reviews, reports, articles, bibliographies), and documenting correctly.

ST 530/530D, Technical Communication for Teachers, 2 cr

Prerequisites: ST 529/529D or departmental waiver

The theory and practice of writing for technology and science: lab reports, proposals, abstracts, and scientific articles. Emphasis will be on audience awareness, editing, writing, and documenting information.

ST 534D Engineering Economic Analysis, 2cr

Prerequisites: ST 550/550BD or departmental waiver

Economic principles applied to decision-making problems in mineral engineering and engineering in general. Compound interest, present worth, rate of return, depreciation, depletion, before and after tax analysis pertinent to project evaluation. *Same as ME 320.*

ST 535/535D Green Construction for Teachers, 2cr

Prerequisites: ST 550/550BD or departmental waiver

The course covers the concepts behind sustainable construction, the history of the green construction movement, materials and processes used, regulatory and certification standards, and presents design examples. A final design project incorporates the cumulative knowledge gained in the course.

ST 536D Fundamentals of Information Technology, 2cr

Prerequisites: ST 556 or departmental waiver

This is an introductory course aimed at presenting state-of-the-art information on technology and technological issues in a broad rather than detailed manner. Major issues affecting all of us and specifically the Information Technology Professionals will be discussed. Although this course is not intended to make us all experts in Information Technology (IT) it will help us understand why IT works the way it does, and give us the groundwork to be more useful IT users and partners. This course will give the student the basic understanding of IT which will help them be more comfortable with the technology around us and use it more efficiently. The student will also have a basic proficiency in an operating system and basic software applications (e.g. word processing, spreadsheets, presentation graphics, and databases).

ST 537 Supercomputer Challenge, 1cr

Prerequisite: departmental waiver

Teachers will learn how to sponsor a Supercomputing Challenge team and how to help students complete an appropriate computational science project in keeping with the Challenge mission statement (described at <http://www.challenge.nm.org/>). The computational project incorporates four components, Project Management, Structured Programming and Design, Mathematical and Agent Based Modeling, and Internet Research and Resources This is a twelve month project and terminates with the final competition at LANL in May.

ST 540, Rockin’ Around New Mexico, 1 cr

Prerequisite: ST 525 or departmental waiver

Explore local geology, including volcanic rocks and hazards, seismic hazards, mountain-building processes, and mineral resources. Two days of the three-day course will be spent in the field, following an introductory day comprising geologic exercises and lecture presentations. Each year, a different New Mexico community hosts this course, co-sponsored by the New Mexico Bureau of Geology.

ST 541, Geology and Mining Engineering for Teachers I, 2 cr

Prerequisites: ST 525 and ST 550/550BD; or departmental waiver

This course is a study of the principles and technology of mineral occurrence, extraction, and refining. Field trips complement lectures and laboratory experiments. Emphasis is on New Mexico base metal deposits.

ST 542D, Timescapes: Momentous, World Altering Events, 2 cr

Prerequisites: ST 525 or departmental waiver

This course is designed for science majors interested in discovering the great events occurring over the last 4.5 billion years of Earth history. Churchill said, "History is just one thing after another," but the history of planet Earth can be viewed as having been shaped by momentous, world-altering events, millions of years apart. These will form the basis of this course. The course will meet distribution requirements for science majors.

ST 543D, Forensic Geology, 2 cr

Prerequisites: ST 525 or departmental waiver

Forensic Geology is a discipline with an ever-expanding role in criminology, environment concerns, and even the war against global terror – geologists have made claims they can tell the locations of terrorist leaders by studying the rocks visible behind them in videotapes. This discipline, a specialty of the geosciences, collects and studies earth materials and their associations, including rocks, sediments, soils, water, and any man-made products that they contain, with attention toward their significance in regulatory and legal areas. The margins of Forensic Geology overlap with other sciences, including biology, chemistry, physics, anthropology, and archeology.

ST 547, Field Techniques in Geology for Teachers, 2 cr

Prerequisites: ST 525 and ST 550/550BD; or departmental waiver

This field-based course shows how geologic mapping and maps are prepared, with in-the-field exercises showing participants how geologic information is collected and plotted on geologic maps. Students will perform rock identification, review faulting and folding of rocks, and the methods used to record geologic data. Field work will be in the Socorro area, with both in-class and in-the-field assignments.

ST 548, Geology of the Southwest—National Parks and Natural Resources, 2 cr

Prerequisites: ST 525 and ST 550/550BD; or departmental waiver

This is a field-based course that involves camping, limited hiking, and visits to national parks and mine sites in the western U.S. Students will camp in areas of spectacular geologic settings. In-the-field assignments will comprise the basis for grading. The regional and local geologic settings of national parks and mineral deposits are reviewed, and the clash between minerals utilization and natural resources occurrence are discussed.

ST 550AD, Mathematics for Teachers, 1 cr

This course is a basic survey of the principles of contemporary mathematics. The course will emphasize the algebra of sets and numbers, exponentials and logarithms, complex numbers, vectors and matrices, and applications in science for each.

ST 550BD, Mathematics for Teachers, 1 cr

Prerequisites: ST 550AD or departmental waiver

This course is a basic survey of the principles of contemporary mathematics. The course will emphasize the algebra of sets and numbers, exponentials and logarithms, complex numbers, vectors and matrices, and applications in science for each.

ST 550, Mathematics for Teachers, 2 cr

This course is a basic survey of the principles of contemporary mathematics. The course will emphasize the algebra of sets and numbers, exponentials and logarithms, complex numbers, vectors and matrices, and applications in science for each.

ST 551AD, Concepts in Mathematics for Teachers, 1 cr

Prerequisites: ST 550/550BD or departmental waiver

The development of some of the great ideas in Mathematics through history, from the concept of number to abstract mathematics, is discussed. Students develop class projects using the covered concepts and history in their own classes.

ST 551BD, Concepts in Mathematics for Teachers, 1 cr

Prerequisites: ST 551AD or departmental waiver

The development of some of the great ideas in Mathematics through history, from the concept of number to abstract mathematics, is discussed. Students develop class projects using the covered concepts and history in their own classes.

ST 552AD, Calculus on a Computer, 1 cr

Prerequisites: ST 550/550BD or departmental waiver

Students learn to use computer software to do single variable calculus. Applications and geometric understanding are emphasized. No previous calculus is required. Student versions of the software are available for purchase.

ST 552BD, Calculus on a Computer, 1 cr

Prerequisites: ST 552AD or departmental waiver

Students learn to use computer software to do single variable calculus. Applications and geometric understanding are emphasized. No previous calculus is required. Student versions of the software are available for purchase.

ST 553, Problem Solving and Recreational Mathematics, 2 cr

Prerequisites: ST 550/550BD or departmental waiver

This course covers problem solving techniques, logic and mathematical arguments, logic puzzles, word problems in algebra, games of strategy for two players, geometrical dissections, tiling puzzles, and basic combinatorics.

ST 554, Mathematical Modeling, 2 cr

Prerequisites: ST 550/550BD; or departmental waiver

Students learn the process of going from a real world problem to a mathematical model and back to an interpretation of results. Students will work in small groups on a wide variety of applications. Projects suitable for classroom use will be developed.

ST 556, Computers and Science Teaching, 2 cr

This course covers the general techniques of computer maintenance and upgrading, including hardware and software. Basic use of the World Wide Web, including sites and techniques of special interest to teachers is also covered.

ST 557, Fractals and Chaos, 2 cr

Prerequisites: ST 550/550BD or departmental waiver

This course covers the development of the basic geometry of fractals, using both deterministic and random methods, the mathematical ideas behind chaos, the connections between the ideas of chaos and fractals, and applications.

ST 558/558D, Probability and Statistics, 2 cr

Prerequisites: ST 550/550BD or departmental waiver

This course covers techniques for the visual presentation of numerical data; descriptive statistics; introduction of sampling and statistical inference, illustrated by examples from a variety of fields.

ST 560 Space Science: Hazardous Asteroids, 2 cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

This course introduces concepts relevant to understanding small bodies in the Solar System and their effect on the near-Earth space environment. The emphasis is on processes that can threaten life on Earth, specifically, a potential asteroid collision. The goal is to expose the student to some of the basic principles of space science (gravity, kinetic energy, astronomical measurement) while using hazardous asteroids as a fun and non-intimidating context for refreshing simple math skills. The format will include lectures, laboratory exercises, and hands-on use of an optical telescope.

ST 561, Weather and Climate, 2cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

In this course, students will study the physical and chemical processes that are important for understanding weather and climate: thermodynamics and the flow of energy in the atmosphere, cloud formation and precipitation, solar and thermal radiation, the greenhouse effect, and the photochemistry of ozone.

ST 562, Radio Astronomy for Teachers, 2 cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

This course is an introduction to observational radio astronomy. It covers some general concepts of astronomy including electromagnetic radiation, motions of astronomical bodies, coordinate systems, as well as small radio telescope operation and data collection. The format will include lectures, field trips, hands on use of optical and radio telescopes, independent team research, documentation, and research presentations. Students must be willing to explore independently and work in teams. Class hours vary during the week to accommodate observing sessions.

ST 563, Optical Astronomy for Teachers, 2 cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

This course exposes the student to the techniques of optical observational astronomy. The emphasis is on correct use of digital cameras and analysis of digital images. In addition, the course covers basic aspects of finding celestial objects in the night sky. Students must be willing to explore independently and work in teams. Class hours vary during the week to accommodate observing sessions.

ST 564/564D, Great Concepts in Physics, 2 cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

This course covers the concepts of physics from the Greeks to the present, the triumphs and questionable philosophical assumptions of the scientific method, revolutions of relativity and quantum theory. Extensive mathematical background and laboratory work are not required.

ST 565, Physics of Aviation, 2 cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

This course is a basic survey of aerodynamics with emphasis on the principles of physics that apply to flight. There is a limited use of mathematics, but

nothing beyond basic algebra. The course uses the method of discovery learning to introduce the principles of physics to flight. The course is a combination of lecture, in-class exercises and take-home activities. There is one short in-class examination and a required in class presentation.

ST 567, Mission to Mars, 2cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

The STARBASE® La Luz Academy Mars Missions Flight, for fifth graders, involves students in planning and preparing for a simulated manned mission to Mars. Teachers guide their students through a series of Base Operations (including creating a mission patch, writing a saga, learning Mars facts, and designing a life support system) in the classroom and then bring students to the culminating Link-Up Day activity in the spring. The goal of the Mars Missions Flight is to increase student interest and motivation for studying science, technology, engineering, and mathematics. Participating teachers can earn graduate credit by submitting the following items: complete lesson plans developed for implementing each of the Base Operation activities in their classroom; a list of resources used in the classroom to accomplish the required Base Operations; and a lessons-learned report based on their participation in this activity.

ST 568 AFRL La Luz Summer Teacher Institute, 1cr

Prerequisites: ST526 and ST 550/550BD; or departmental waiver

This is a hands-on, inquiry-based course that focuses on science, technology, engineering, and mathematics (STEM) activities from the AFRL La Luz Academy. Students will earn one credit hour by completing a specified team STEM project, using a systems engineering approach, during the weeklong course. Opportunities to collaborate with scientists and engineers, as well as tours of AFRL facilities, will be incorporated into the course, as available. An additional credit hour is available the following summer for those students who develop and implement STEM lesson plans as Teacher Institute Fellows during the school year and present these lesson plans at the AFRL La Luz Academy Teacher Institute Symposium.

ST 569 Optics for Teachers, 2cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

This course considers the characteristics and behavior of light. Drawings and a few algebraic equations provide complementary means – concrete and abstract – for predicting the position, orientation, size and type of images created in a variety of optical instruments and natural circumstances. Participants receive an Introductory Optics System kit, and individual projects and class activities insure familiarity and the ability to adapt the kit for a range of classroom levels. The study of light introduces various “action at a distance” phenomena. While this course affirms that many observed phenomena require a considerably more

sophisticated model for optics, a solid grounding in geometric optics is sufficient for the design of state of the art instruments.

ST 570 ELECTRICITY, 1 cr

Prerequisites: ST 526 and ST 550/550BD; or departmental waiver

Electricity and Magnetism are behind almost all modern technologies. This first course in electricity covers what you would need to teach electricity and circuits for grades 6-12. We will cover forces on charges, electric fields, voltage, current, power and electrical circuits. You will be sent a lab kit so that you can demonstrate static electric effects and build and test simple circuits. This course will introduce new mathematics (vectors) to describe electric fields and you will learn to calculate fields of multiple charges. It will also review the trigonometry and fractions that were introduced in ST550, and apply them to electric forces and circuit analysis.

ST 571 ELECTROMAGNETISM AND LIGHT, 1 cr

Prerequisites: ST 570 or departmental waiver

This follow-on course to Electricity (ST570) introduces magnetic fields and forces and how they interact with electric currents. Dipole moment and magnetic strength are also introduced. The vector cross product is used to calculate the direction of magnetic forces. The mathematics of sine waves is reviewed and then applied to understanding wavelength, frequency, refraction, interference and diffraction. Your lab kit will allow you to demonstrate image formation by lenses and diffraction of a laser, to build a simple motor, and to build a galvanometer. This course should lead to increased confidence in physics, applied math, and basic engineering skills.

ST 572D, New Mexico Science and Scientists I, II, III, 2 cr each

Prerequisites: none

New Mexico is unique in the U.S. in its concentration of scientists and in the range of science being done here. Much of the research is on the cutting edge, be it deep-space radio astronomy, New World archeology, or the newest computer chips. New Mexico scientists are at work in universities, colleges, museums, institutes, national laboratories, the state and federal government, regional entities such as the Middle Rio Grande Conservancy, and in mining and other private industries. The course will introduce students to many of these scientists in an informal, conversational setting. This course is designed for both science and non-science majors.

Section I: Earth, Mars, and Meteors

Section II: Biology and Evolution

Section III: Energy, Environment and Materials

ST 577 Renewable Energy (extensive use of field trips), 2 cr

Prerequisites: ST 524/524D and ST 526; or departmental waiver

This is a survey course that explores the state of energy use, production, economics and environmental issues by field trips, lectures and readings. Topics explored in this course include sources of energy, impacts of energy production and use, methods of production and delivery as well as environmental, economic and political issues. Field trips will allow students to see firsthand alternative energy facilities, sites where alternative energy is in use, traditional mines and power plants. Students will meet with personnel at these facilities. A goal of the course is to enable teachers to present information in their classroom from the perspective of real experience.

ST 577D Renewable Energy (web based, no field trips), 2 cr

Prerequisites: ST 524/524D and ST 526; or departmental waiver

Energy and the energy crisis and their association with non-renewable sources are covered and renewable sources and new technologies are then covered for a contrasting perspective. Weekly course modules explain fossil fuel origins, uses, and abuses, plus the renewable energy sources wind, solar, biomass, hydroelectric, ocean/tidal, and geothermal plus virtual field trips. The scope of this course encompasses both local and global energy issues and politics plus new technology and innovations. The goal is to give a good understanding of the alternatives to fossil fuel use and ways to reuse and conserve resources. Taking this course will prepare the student to teach energy generation and conservation in his or her own classroom.

ST 578D The Chemistry of Natural Products, 2cr

Prerequisites: ST 524/524D or departmental waiver

This course begins with an overview of organic compounds; examining each of the major functional groups. A number of different classes of naturally derived organic compounds are then considered. These include the sugars, alkaloids (opiates, nicotine, etc.), essential oils, taxanes and cannabinoids. Sulfur based compounds are also discussed. In particular, we are interested in understanding the natural sources for these compounds and methods of isolation. Additionally, we would like to understand their physiological effects, mode of action and metabolism.

ST 579D Concepts in Chemistry: Development of Atomic

Theory, 2cr

Prerequisites: ST 524/524D or departmental waiver

This course examines the classic experiments in chemistry and physics that underpin our current understanding of atomic structure. We begin by examining the classification of matter, the fundamental laws of chemical combination and the development of a workable atomic theory. Then, we consider the discovery and characterization of the subatomic particles; the electron, proton and neutron. The structure of the atom is next discussed. We look at the experimental evidence for quantum physics and how it can be used to understand the electronic structure of the atom. Finally, simple bonding theories are presented.

ST 580D Introduction to Biochemistry, 2 cr.

Prerequisites: ST 524/524D or departmental waiver

This course will consider the structure and function of the four basic classes of biomolecules. These are proteins, carbohydrates, lipids and nucleic acids. A discussion of enzyme function, membrane construction, metabolism and photosynthesis will also be included. Finally, the role of nucleic acids in protein synthesis will be considered. Special topics to be taken up are vitamins, neurotransmitters and viruses.

ST 581, Directed Study, cr to be arranged

Study under the guidance of a member of the graduate faculty. In general, subject matter will supplement that available in other graduate course offerings.

ST 590, Independent Study, 3 cr

An IS provides the student with an opportunity to engage in a plan of study under the supervision of NMT Faculty to (a) explore in more depth or detail an area to which the student has been introduced in previous courses or in the field of science-based education and (b) contribute to the knowledge content and/or the application of the knowledge content of the selected area. An IS is intended to be a project initiated by the student and designed in conjunction with his/her advisory committee.

ST 591, Thesis (master's program), 6 cr

A Thesis is similar to an IS except that it normally involves research over an extended period of time and follows the guidelines of the Academic Advisor's or Research Advisor's Department. In general, the requirements for a Master of Science for Teachers student completing a thesis are no different from the requirements for any other graduate student completing a thesis within the same department.

Engineering

Accreditation

The undergraduate programs in Chemical Engineering, Civil Engineering, Electrical Engineering, Environmental Engineering, Materials Engineering, Mechanical Engineering, Mineral Engineering, and Petroleum and Natural Gas Engineering are accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

The undergraduate program in Computer Science is accredited by the Computing Accreditation Commission of ABET, <http://www.abet.org>.

Professional Examinations

Undergraduate engineering majors in Chemical, Civil, Environmental, and Mechanical Engineering are required to take the Fundamentals of Engineering (FE) exam as a requirement for graduation. All engineering students are encouraged to take this exam, as it is the entry-level requirement for those individuals who intend to attain a professional engineer status. The FE exam is a national, computer-based test; therefore, the results are transferable to any state or territory of the United States. See the NCEES website (<http://www.ncees.org>) for details.

Minors

- Aerospace Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Science
- Electrical Engineering
- Environmental Engineering
- Explosives Engineering
- Materials Engineering
- Mechanical Engineering
- Mineral Engineering
- Optical Science and Engineering
- Petroleum Engineering
- Polymer Science Engineering

Engineering Science

Courses in Engineering Science deliver fundamental topics that are common across engineering programs. No specific degree is offered. For further information, contact the Dean of Engineering.

Engineering Science Courses:

ES 110, Introduction to Engineering, 2 cr, 1 cl hr, 3 lab hrs

Corequisite: MATH 103

Students will be introduced to the profession of engineering and gain fundamental engineering skills with an emphasis on engineering design and problem solving. Topics covered include: problem definition and presentation of solution; the engineering design process; working in a team environment, engineering graphics by hand and in SolidWorks; graphical solutions and simple modeling in Microsoft Excel. Students will learn the process of designing, building, modeling, and optimizing a system through a semester long design project.

ES 111, Computer Programming for Engineers, 3 cr, 2 cl hrs, 3 lab hrs

Corequisite: MATH 131

Engineering computer problem solving using a high-level programming language. Algorithm and program development and documentation. Emphasis is placed on programming logical and concise solutions to a variety of problems drawing from engineering disciplines of mechanics, civil, electrical, industrial, and economics.

ES 201, Statics, 3 cr, 3 cl hrs

Prerequisites: PHYS 121

Corequisite: MATH 231

Forces and moments acting on rigid bodies in equilibrium, distributed forces including hydrostatic forces, friction, moment of inertia, and problem solution by computer.

ES 216, Engineering Fluid Mechanics, 3 cr, 3 cl hrs

Prerequisite: ES 201

Corequisite: MATH 231

Fundamentals of fluid mechanics including fluid statics, velocity of continuous media, continuity, and momentum balance. Introduction of laminar and turbulent flows, similitude, dimensionless analysis, Bernoulli's equation, friction factor, introduction to pump and compressor selection.

ES 302, Mechanics of Materials, 3 cr, 3 cl hrs

Prerequisite: ES 201 passed with grade C or better; MATH 231

Relationships between external forces acting on deformable bodies and the stresses and strains produced; tension, compression, torsion, shear, bending, and problem solution by computer. Failure criteria. Design of members and systems.

ES 303, Engineering Dynamics, 3 cr, 3 cl hrs

Prerequisite: ES 201 passed with grade C or better; MATH 335

Kinematics and kinetics of particles, systems of particles, and rigid bodies; momentum and energy methods; and problem solution by computer.

ES 305, Engineering Analysis, 3 cr, 3 cl hrs

Prerequisites: ES 216, 302; MATH 335; or consent of instructor

Solution of linear systems of equations using Gaussian elimination and matrix methods. Scalar and vector fields; gradient; divergence; curl; line, surface and volume integrals; Green's theorem and Stokes' theorem. Solutions to partial differential equations from heat transfer, mechanical vibrations, and fluid mechanics using separation of variables, series and Laplace transforms. (Same as MENG 305)

ES 316, Engineering Economics, 3 cr, 3 cl hrs

Prerequisite: Junior Standing

Professional ethics. Economic decision-making for engineering alternatives. Use of compound interest and depreciation calculations to compare the relative economy of investments and procedures. The application of economic principles such as return on investment, leverage, and present worth to engineering problems. Use of PC computer programs. This course is not available for social science credit.

ES 332, Electrical Engineering, 3 cr, 3 cl hrs

Prerequisites: PHYS 122; MATH 335

Analysis of steady state linear circuits, balanced three-phase power, transformers. Electromechanical energy conversion. Semiconductor devices and applications.

ES 347, Thermodynamics, 3 cr, 3 cl hrs

Prerequisites: CHEM 122; MATH 132

Corequisites: ES 216; PHYS 122; MATH 231

Introduction of the first and second laws of thermodynamics and their applications to engineering power cycles. Carnot cycle, Rankine cycle, refrigeration cycle, Otto cycle, and Diesel cycle.

ES 350, Heat and Mass Transfer, 3 cr, 3 cl hrs

Prerequisite: ES 216, ES 347

Corequisite: MATH 335

Fundamentals of heat transfer, steady- and unsteady-state conduction, convection and radiation. Fundamentals of mass transfer, steady and unsteady state, diffusion, and convection. Dimensionless analysis, equipment.

ES 405L, Instrumentation, Measurement, and Process Control Laboratory, 1 cr, 3 lab hrs

Prerequisite: ES 111; PHYS 122

Laboratory exercises involving instrumentation and design of basic control systems.

ES 489, 489D, Special Topics in Engineering Science, 3 cr, 3 cl hrs**ES 491, Directed Study, cr to be arranged**

Chemical Engineering

(www.nmt.edu/~cheme)

Associate Professors Leclerc (Chair of the Department), Tartis
 Assistant Professor Choudhury, Chowdhury
 Adjunct Faculty Bickel, Dunston, Lee, McCoy
 Visiting Professor Calvert
 Laboratory Associate Price
 Emeritus Professor Bretz

Degree Offered: B.S. in Chemical Engineering

Chemical Engineering is considered one of the base engineering disciplines with applications in nearly every facet of life. The development and production of food, pharmaceuticals, fuels, semiconductors, detergents, fertilizers, plastics, and paper have all been driven by the ingenuity of chemical engineers. Current frontiers being explored by Chemical Engineers include biofuels, renewable energy, new batteries, nanotechnology, fuel cells, microsensors, explosives, and other critical technologies important to the 21st century. Chemical engineering graduates find challenging careers in a broad spectrum of fields including petroleum, chemical, plastics, paper, semiconductor, pharmaceutical, and biotechnology. At the same time, the breadth of a chemical engineering background helps graduates flourish in careers such as medicine, patent law, and technical marketing.

Throughout the Chemical Engineering curriculum, we focus on the development of complete engineers who can foster innovation through know-how and champion ideas through effective communication. We deliver a thorough education with insightful teaching, an innovative curriculum, research opportunities, summer job experiences, and channels for permanent, successful careers. Each year, our program is reviewed by an outside advisory board of professionals, who help ensure that our graduates are well prepared for lifelong successful careers in the exciting array of fields open to chemical engineers.

An important part of the chemical engineering experience at New Mexico Tech is the abundance of opportunities to participate in cutting edge research projects of our faculty and staff. Virtually all of our graduates engage in significant research projects and/or internships while working toward B.S. degrees in Chemical Engineering. Examples of areas of research open to Tech chemical engineering undergraduates include energetic materials, fuel cells, nano-composite materials, membrane separations, computer simulation, bioenergy, and thin film plasma processing. Numerous opportunities exist for summer research internships, including employment at the nearby Sandia and Los Alamos national labs as well as the research divisions on campus.

To learn more, the Student Handbook section of the Chemical Engineering website (www.nmt.edu/~cheme) is an excellent resource with quick links and great insights to taking advantage of the outstanding educational opportunities at New Mexico Tech.

Program Educational Objectives

The following objectives have been established by the program faculty in conjunction with our students and advisors from industry. They describe the characteristics and expected accomplishments of our future alumni.

1. Our graduates will be engaged in careers covering the spectrum of fields, which require a command of the principles of Chemical Engineering, or in pursuit of/complete post graduate degrees in fields such as engineering, the sciences, business, law, or medicine.
2. Our graduates will be active in the professional community by participating in professional societies, obtaining licensure, and other related activities.

Undergraduate Program

Bachelor of Science in Chemical Engineering

Minimum credit hours required – 136

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- ChE 110 (1), 110L (1), 326 (3), 327 (3), 345L (1), 349 (3), 351 (3), 352 (3), 371 (3), 443 & 443L (3), 445L (1), 461 (3), 462 (3), 485 (1)
- CHEM 311 & 311L (4), 331 & 331L (4), 333 & 333L (4)
- ES 201 (3), 216 (3), 302 (3), 347(3), 350 (3), 405L (1)
- EE 211 (3) or ES 332 (3)
- MATH 231 (4), 335 (3)
- MATE 202 & 202L or 235 & 235L (4)
- Engineering/Technical Electives (9) Upper-division engineering or other approved courses. These electives should be Chemical Engineering, other engineering, chemistry, biology, mathematics, physics or computer science courses at the 300-, 400-, or 500-level.

Chemical engineering majors must maintain a minimum GPA of 2.0 in required courses in order to graduate. Courses used for degree, including general degree requirements, may not be taken on an S/U basis.

Chemical engineering majors are required to take the Fundamentals in Engineering (FE) exam as a requirement for graduation.

Sample Curriculum for the Bachelor of Science in Chemical Engineering

To help plan your course of study, be sure to use the degree flowchart found in the Student Handbook at www.nmt.edu/~cheme

Semester 1

- 2 ChE 110 & 110L (intro to chemical engineering)
- 3 ENGL 111 (college English)
- 4 MATH 131 (calculus I)
- 4 CHEM 121 & 121L (general)
- 3 Social Science
- 16 Total credit hours

Semester 2

- 3 ENGL 112 (college English II)
- 4 MATH 132 (calculus II)
- 4 CHEM 122 & 122L (general)
- 5 PHYS 121 & 121L (general)
- 16 Total credit hours

Semester 3

- 3 ChE 326 (principles of chemical engineering I)
- 4 MATH 231 (calculus III)
- 3 ES 201 (statics)
- 4 CHEM 311 & 311L (analytical)
- 3 Social Science
- 17 Total credit hours

Semester 4

- 3 ES 216 (fluid mechanics)
- 3 ES 347 (engineering thermodynamics)
- 3 MATH 335 (ordinary differential equations)
- 5 PHYS 122 & 122L (general)
- 3 ChE 327 (principles of chemical engineering II)
- 17 Total credit hours

Semester 5

- 3 ChE 349 (ChE thermodynamics)
- 3 ChE 371 (chemical engineering analysis)
- 3 ES 350 (heat and mass transfer)
- 1 ES 405L (instrumentation)
- 4 CHEM 331 & 331L (physical)
- 3 Social Science
- 17 Total credit hours

Semester 6

- 1 ChE 345L (junior design)
- 3 ChE 351 (kinetics)
- 3 ChE 352 (separation processes)
- 3 Engineering/Technical Elective
- 3 ENGL 341 (technical writing)
- 4 MATE 202 & 202L or 235 & 235L (materials engineering)
- 17 Total credit hours

Semester 7

- 1 ChE 445L (unit operations lab)
- 3 ChE 461 (plant design I)
- 1 ChE 485 (senior seminar)
- 2 ChE 443 (process control)
- 1 ChE 443L (process control lab)
- 4 CHEM 333 & 333L (organic)
- 3 Engineering/Technical Elective
- 3 Humanities/Social Science
- 18 Total credit hours

Semester 8

- 3 ChE 462 (plant design II)
- 3 ES 302 (strength of materials)
- 3 EE 211 (circuits) or ES 332 (electrical engineering)
- 3 Engineering/Technical Elective
- 3 Humanities
- 3 Social Science
- 18 Total credit hours

Minor in Chemical Engineering

Minimum credit hours required—19

The following courses are required:

- ChE 326 (3),
- Three of: ES 216 (3), ES 347 (3), ES 350 (3), ChE 349 (3), ChE 371 (3)
- One of: ChE 351 (3), ChE 352 (3), ChE 443 & L (2+1)
- One of: CHEM 311 & L (4), CHEM 331 & L (4), CHEM 333 & L (4)

Minor in Polymer Science

Minimum credit hours required—19

The following courses are required:

- CHEM 334 (3), 446 (3)
- MATE 202 & 202L (4) or 235 & 235L (4)
- MATE 351 (3), 474 (3)
- ChE 473 (3)

Chemical Engineering Courses:

ChE 110, Introduction to Chemical Engineering, 1 cr, 1 cl hrs

Students will gain fundamental engineering skills that apply to all engineering disciplines through problem and cooperative based learning exercises and attain a clear understanding of what chemical engineers practice versus other engineering disciplines, in both traditional and contemporary work environments and careers. This course will introduce engineering calculations such as material and energy balances, cost analysis, and engineering software programs.

ChE 110L, Introduction to Chemical Engineering Lab, 1 cr, 1 lab hr

This lab focuses on firsthand experience of engineering design, calculations, and simulations using ChemCAD, Lab VIEW, and Excel. Additionally, data acquisition and analysis will be introduced. Small teams will design, build, and test a system, resulting in a written report, oral presentation, and design competition.

ChE 326, Principles of Chemical Engineering I, 3 cr, 3 cl hrs

Prerequisite: CHEM 121

Corequisite: MATH 132

Offered fall semester

Introduction to stoichiometric computations. Calculations of energy and material balance. Elementary process analysis and reactor design. Single and multi-phase systems. (Same as METE 326)

ChE 327, Principles of Chemical Engineering II, 3 cr, 3 cl hrs

Prerequisite: ChE 326

Corequisite: MATH 231

Offered spring semester

Introduction to non-steady state, transient material and energy balances. Solution methods using logic programming, spreadsheets, and process simulation software. Statistical process analysis.

ChE 345L, Chemical Engineering Design Lab, 1 cr, 3 lab hrs

Prerequisites: ES 347, ChE 326

Corequisite: ES 350

Offered spring semester

Team-oriented project design. Introduction to design fundamentals and creative problem-solving techniques. Written and oral presentations summarizing team progress.

ChE 349, Chemical Engineering Thermodynamics, 3 cr, 3 cl hrs

Prerequisites: MATH 231; CHEM 121, PHYS 121; ES 347 is recommended

Offered fall semester

The theory and engineering applications of the properties of mixtures, phase and chemical reaction equilibria. (Same as MATE 350)

ChE 351, Chemical Process Kinetics, 3 cr, 3 cl hrs

Prerequisites: ChE 326, 349, MATH 335

Corequisite: ES 350

Offered spring semester

Fundamentals of chemical reaction kinetics and chemical reactor design. Development of rate equations for both homogeneous and heterogeneous reactions, catalysis, diffusion-controlled reactions, and transport processes. (Previously offered as ChE 451)

ChE 352, Separation Processes, 3 cr, 3 cl hrs

Prerequisites: ChE 326, 349

Corequisite: ES 350

Offered spring semester

The process approach to solving problems that involve equilibrium in binary and multicomponent mixtures. Phase equilibrium, absorption, distillation (binary and multicomponent), liquid-liquid extraction, leaching. Design of staged operations for separating gas-liquid, liquid-liquid, solid-liquid, and gas-solid mixtures. (Previously offered as ChE 442)

ChE 371, Solution Methods for Chemical Engineers, 3 cr, 3 cl hrs

Prerequisites: ChE 327

Corequisites: MATH 335, ES 350

Offered fall semester

Application of analytic and numeric solution techniques to problems in chemical engineering thermodynamics, fluid transport, heat transfer, mass transfer, kinetics and process control. Topics covered include solution of sets of linear and nonlinear algebraic equations, ordinary differential equations, and partial differential equations. Emphasis will be on solving problems the student will encounter in the field of chemical engineering.

ChE 443, Process Dynamics and Control, 2 cr, 2 cl hrs

Prerequisites: MATH 335

Corequisites: ChE 371

Offered Fall Semester

Process dynamics and control theory applied to chemical, mechanical, and other engineering processes. Design of control systems.

ChE 443L, Chemical Process Dynamics & Control Lab, 1 cr, 3 lab hrs

Corequisite: ChE 443

Computer modeling of system dynamics. Design, implementation, and tuning of process control systems for chemical processes.

ChE 445L, Unit Operations Lab, 1 cr, 3 lab hrs

Prerequisite: ChE 351, 352

Offered fall semester

Laboratory exercises to illustrate heat exchange, fluid flow, and mass transport phenomena in common unit operations found in the chemical process industries.

ChE 461, Chemical Plant Design, Economics, and Management I, 3 cr, 1 cl hr, 6 lab hrs

Prerequisites: ChE 351 and ChE 352

Offered fall semester

A two-semester sequence of courses in which a design project is used to illustrate principles and processes of chemical plant design, economics, and management. Lecture topics include intellectual property, capital and operating cost estimation, energy conservation, design optimization and scaling of chemical processes. Use of commercially available process simulation software emphasized.

ChE 462, Chemical Plant Design, Economics, and Management II, 3 cr, 1 cl hr, 6 lab hrs

Prerequisite: ChE 461

Offered spring semester

Continuation of ChE 461.

Elective Courses

ChE 463, 463D, Design and Analysis of Experiments, 3 cr, 3 cl hrs

Prerequisite: Senior standing

Methods of statistics and modeling important to many problems in materials science and engineering. Examples are chosen from a number of actual experiences. Safety considerations and experiment design including analysis of risk, how risks may be integrated, and how formal procedures should be established. The use of information sources, such as materials safety data sheets (MSDS). (Same as MATE 430)

ChE 464, Natural Gas Engineering, 3 cr, 3 cl hrs

Prerequisite: PETR 245 or ChE 349

Offered fall semester

Composition and properties of natural gas. Gas separator design. Recovery of liquefiable products from gas. Conditioning, transmission, and compression, measurement of gas, gas pipeline design, and gas storage. (Same as PETR 464)

ChE 465, Catalyst Characterization Techniques, 3 cr, 3 cl hrs

Prerequisite: ChE 349 or MATE 350 or CHEM 332 or instructor's consent

The course provides an overview of techniques used to characterize catalytic materials including data analysis and linking physical and chemical properties to catalytic activity at the laboratory and process level. Topics include x-ray methods, neutron scattering methods, physical adsorption, chemical adsorption, temperature programmed techniques, photoelectron spectroscopy, vibrational spectroscopy, and electron microscopy.

ChE 470, Fuel Cell Technology, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

The principles of fuel cell technology, including classification of fuel cells and operating mechanisms. Analysis of the underlying thermodynamics and physical factors which govern fuel cell performance and efficiency. Cell components and integrative cell design.

ChE 472, 472D, Advanced Transport Phenomena, 3 cr, 3 cl hrs

Prerequisite: ES 216 and 350 or MATE 314 or consent of instructor

Advanced topics in momentum, heat, and mass transfer. Newtonian and non-Newtonian fluid behavior and laminar flow problems, elementary turbulent flow concepts, energy balance applications in incompressible fluid flow, flow and vacuum production. Fourier's law and thermal conductivity of materials, steady state and time dependent heat conduction, application in solidification, elementary convective heat transfer. Diffusivity of materials, diffusion in gases, liquids and solids and through porous media, time dependent diffusion, and interphase mass transfer.

ChE 473, Polymer Materials Engineering, 3 cr, 3 cl hrs

Prerequisite: MATE 202 or consent of instructor

Offered every fall semester

Introduction to classes and performance properties of polymeric materials. Methods of polymer synthesis and processing. Special emphasis on structure, viscoelasticity, and mechanical properties.

ChE 474, Polymer Processing and Characterization, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Consent of instructor

The basics of rheology, calorimetry and mechanical testing are covered. A specific polymer is used (e.g., an epoxy) throughout the course and the processing of this polymer is covered. Students are expected to acquire a working knowledge of the instrumentation and analysis tools used in the course. These include rheometers, calorimeters, and mechanical testing. The primary analysis tool is Kaleidagraph software. (Same as MATE 474.)

ChE 475, 475D, Explosives Surety, 3 cr, 3 cl hrs

Prerequisite: Upper-class standing or consent of instructor

Offered spring semester

An introduction to explosives and other energetic materials. The basic chemical compositions, properties and environmental effects of commercial, military, and improvised (terrorist) explosives and some pyrotechnics will be compared. The basic physics of shock waves and detonation. Explosive effects, blast detection, tagging and environmental issues. Case studies or recent bombings will be used to describe a variety of terrorist approaches. Safety in handling of explosive materials and classifications for transportation and storage. (Same as EXPL 414.)

ChE 476 Drug Delivery Techniques, 3 cr, 3 cl hrs

Prerequisite: Senior standing or consent of instructor

Focus is on current developments in drug delivery techniques, with only a brief discussion of common clinical techniques. The first portion of the class focuses on various delivery mechanisms and the tools needed to validate successful targeted drug delivery (both in vitro, in vivo and diagnostic tools). The second part of the course focuses on current developments in drug delivery based on published research articles. Students will read, digest, and critically analyze scientific work from leading research laboratories. Students will also gain valuable communication tools, as each student will present an article of interest to the class. Finally, the third part of the course focuses on important materials characterization methods such as biological sample prep, SEM, TEM, DSC, Flow Cytometry, Fluorescence Microscopy, ELISA Assays. Shares lecture with MATE 576 but is graded separately and additional work is required at the graduate level.

ChE 485, Senior Seminar, 1 cr, 3 lab hrs

Prerequisite: Senior standing or consent of instructor

Offered fall semester

Student and outside speaker presentations of topics of current interest. Peer and video review of each student's work. Career planning.

ChE 491, Independent Study, hrs and crs to be arranged

Prerequisite: Consent of instructor

Individual study of chemical engineering problems of special interest.

Faculty Research Interests

Calvert—Biomaterials, 3-D Printing, Bioprinting,

Hydrogels, Gel-Based Drug Delivery, Gel Sensors

Choudhury—Computational Modeling of Materials for the Energy and Environment; Specific Research Areas Include Surface Engineering, Catalysis, Gas Sensors, Proton Transport Membranes, Sorbent Materials and CO₂ Reduction

Chowdhury—Plasmonic nanomaterials, Nanoparticle-Bioparticle Interactions, Single Molecule Microscopy, Proton Transport Membranes, Plasmon Enhanced Photocatalysis

Leclerc—Catalysis, Reactor Design, Alternative Fuels, Biofineries, Hydrogen Production

Tartis - Biomedical Engineering, Targeted Drug Delivery

Civil Engineering

Professor Richardson (Chair of the Department)

Associate Professor Wilson

Assistant Professor Cook,

Adjunct Faculty Ghosh, Hendrickx, McCord, McMullin, Kuhn

Degree Offered: B.S. in Civil Engineering

Department Mission Statement

The primary objective of this program is to produce well-balanced civil engineers capable of entering the civil engineering profession or continuing their studies at the graduate level. Graduates will be well-prepared to solve current civil engineering problems, and they will have the ability to adapt to problems of the future.

The achievements of civil engineers are well-known to the general public, because civil engineers build the world's infrastructure. In doing so, they can shape the history of nations. Projects that civil engineers work on include: airports, bridges, buildings, dams and waterways, drainage and sewer systems, city roads, and highways.

The undergraduate program offers a balanced approach to civil engineering education. Students take a common core of civil engineering courses, and they can specialize in the areas of geotechnical, water resources, or structural engineering. The program is also designed to give students a solid foundation in engineering and science. Students take courses in chemistry, physics, and math, in addition to a core set of engineering courses common to most engineering disciplines. The civil engineering courses teach students the fundamentals of engineering design, as well as potential applications. Students are taught how to use computer software to expedite the design process, and they are also taught how to balance engineering designs with economic constraints. During their senior year, undergraduate students work with a professor on a design project.

Program Educational Objectives

1. To develop graduates that function successfully in the fundamental areas of civil engineering, and within a specialty, such as structural, geotechnical or water resources engineering.
2. To prepare graduates for advanced education in civil engineering and related fields, and for professional licensure.

Undergraduate Program

Bachelor of Science in Civil Engineering

Minimum credit hours required—132

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- CE 101 (1), 201 (3), 301 (3), 302 (3), 401 (3), 402 (3), CE 406 (3), CE 407 (3), 413 (3), 423(3), 481 (3)
- ES 316 (3)
- ES 110 (2), 111 (3), 201 (3), 216 (3), 302 (3)
- MATH 231 (4), 283 (3), 335 (3)
- ME 220 (3), 420(3)
- Basic Science Elective— 3 credits from the following: BIOL 111, EARTH 101, EARTH 120, EARTH 130, EARTH 140, EARTH 150. Students are not required to take the accompanying lab unless it is required by the Biology/Earth Science department.
- Technical Electives (12): Minimum of 12 credit hours from the list of approved civil engineering electives. Students may take approved elective courses from more than one specialty area to satisfy the B.S. degree without prior approval from their advisor or the Department Chair. Courses are grouped by specialty to assist students who may want to specialize in a particular area.

Civil engineering approved electives include:

- **Geotechnical** (12): CE 420 (3), CE 422 (3), ME 360 (3), ME 409 (3), ME 422 (3), ME 427 (3), ME 434 (3), EXPL XXX (3)
- **Water Resources** (12): ENVE 201 (3), ENVE 301 (3), ENVE 303(3), ENVE 304 (3), ENVE 406 (3), EARTH 440 (4), EARTH 441 (1), EARTH 442 (1), EARTH 443 (1), ES 347 (3), ES 350 (3)
- **Structural** (12): CE 410 (3), CE 412 (3), CE 414 (3), CE 418 (3), CE 420 (3), MATE 470 (3), MENG 304 (3), MENG 441 (3), ME 409 (3), ME 434 (3) , EXPL XXX (3)

Additional technical electives must be approved by the Department Chair.

Students pursuing a B.S. in Civil Engineering must take all engineering courses for a letter grade.

Civil engineering majors must maintain a minimum GPA of 2.0 in required courses in order to graduate. Civil engineering majors are required to take the Fundamentals in Engineering (FE) exam as a requirement for graduation.

Sample Curriculum for the Bachelor of Science Degree in Civil Engineering

Semester 1

- 1 CE 101 (civil engineering seminar)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 2 ES 110 (drafting)
- 4 MATH 131 (calculus)
- 3 Basic Science*

17 Total credit hours

* Basic Science Elective from one of the following:
BIOL 111, EARTH 101, EARTH 120, EARTH 140, EARTH 150

Semester 2

- 3 ENGL 112 (college English)
- 3 ES 111 (computer programming)
- 4 MATH 132 (calculus)
- 5 PHYS 121 & 121L (general)

15 Total credit hours

Semester 3

- 4 CHEM 122 & 122L (general)
- 3 ES 201 (statics)
- 4 MATH 231 (calculus)
- 5 PHYS 122 & 122L (general)

16 Total credit hours

Semester 4

- 3 ES 216 (fluid mechanics)
- 3 ES 302 (mechanics of materials)
- 3 MATH 335 (ordinary differential equations)
- 3 ME 220 (surveying and map preparation)
- 6 Humanities / Social Science

18 Total credit hours

Semester 5

- 3 CE 201 (materials, properties, and testing)
- 3 CE 302 (structures)
- 3 ME 420 (soil mechanics)
- 3 ENGL 341 (technical writing)
- 3 MATH 283 (statistics)
- 3 Social Science

18 Total credit hours

Semester 6

- 3 CE 301 (construction engineering)
- 3 CE 401 (finite element analysis)
- 3 CE 402 (transportation)
- 3 ES 316 (engineering practice and economics)
- 3 CE Elective
- 3 Humanities

18 Total credit hours

Semester 7

- 3 CE 406 (steel)
- 3 CE 407 (concrete)
- 6 CE Electives
- 3 Humanities

15 Total credit hours

Semester 8

- 3 CE 413 (foundation design & analysis)
- 3 CE 423 (open channel hydraulics)
- 3 CE 481 (senior design)
- 3 Humanities
- 3 CE Elective

15 Total credit hours

Approved Civil Engineering Electives

CE students must take a minimum of 12 elective credit hours. Students may take approved elective courses from more than one specialty area to satisfy the B.S. degree without prior approval from their advisor or the Department Chair. Courses are grouped by specialty to assist students who may want to specialize in a particular area.

Water Resources Engineering

- 3 ENVE 201 (environmental engineering)
- 3 ENVE 301 (applied principles of environmental engineering)
- 3 ENVE 303 (water treatment process design)
- 3 ENVE 304 (wastewater treatment process design)
- 3 ENVE 406 (environmental engineering unit operations)
- 4 EARTH 440 (hydrological theory and field methods)
- 1 EARTH 441 (aquifer mechanics)
- 1 EARTH 442 (vadose zone processes)
- 1 EARTH 443 (atmospheric dynamics and rainfall processes)
- 3 ES 347 (engineering thermodynamics)
- 3 ES 350 (heat and mass transfer)

Geotechnical Engineering

- 3 CE 420 (pavement design)
- 3 CE 422 (geotechnical waste containment design)
- 3 ME 360 (exploration and field mapping)
- 3 ME 409 (design of structures)
- 3 ME 422 (rock mechanics)
- 3 ME 427 (site investigation)
- 3 ME 434 (drilling & blasting)
- 3 Some explosives (EXPL) courses – check with Department Chair

Structural Engineering

- 3 CE 410 (reinforced masonry and timber design)
- 3 CE 412 (advanced design of steel structures)
- 3 CE 414 (advanced design of concrete structures)
- 3 CE 418 (structural dynamics)
- 3 CE 420 (pavement design)
- 3 MATE 470 (corrosion phenomena)
- 3 MENG 304 (advanced strength of materials)
- 3 MENG 441 (dynamics and vibrations in structural design)
- 3 ME 409 (design of structures)
- 3 ME 434 (drilling & blasting)
- 3 Some explosives (EXPL) courses – check with Department Chair

Additional technical electives must be approved by the Department Chair.

Minor in Civil Engineering

Minimum credit hours required – 18

The following courses are required:

- 18 total credit hours of CE courses, ME 420, or ME 422

Civil Engineering Courses

CE 101, Civil Engineering Seminar, 1 cr, 1 cl hrs

Brief overview of civil engineering topics, including structures, water resources, geotechnical and transportation engineering in the form of seminars by faculty, and guest speakers from industry, consulting, and government.

CE 201, Construction Materials, Properties, and Testing, 3 cr, 3 cl hrs

Prerequisite: CHEM 122

Mechanical behavior of engineering materials, including metals, ceramics, polymers, concrete, wood, bitumens, and asphaltic concretes; explanations of macroscopic behavior in terms of phenomena at the microscopic level.

CE 301, 301D, Introduction to Construction Engineering, 3 cr, 3 cl hrs

Topics covered include: contracting and bonding, planning and scheduling, estimating, project control, and productivity models.

CE 302, 302D, Introduction to Structural Engineering, 3 cr, 3 cl hrs

Prerequisites: ES 201, 302 or consent of instructor

Basic topics in the analysis, behavior, and design of trusses and framed structures under static loads; analysis topics include member forces in trusses, shear and moment diagrams, deflections, simple applications of the force method and slope–deflection; and an introduction to computer applications by means of a general purpose structural analysis program.

CE 401 – Finite Element Analysis for Civil Engineers, 3 cr, 3 cl hrs

Prerequisite: CE 302 or consent of instructor

Introduction to finite element analysis (FEA) for Civil Engineering students. Students will learn the fundamentals of FEA, and they will learn to use software packages to analyze complex structures. Topics include: 1-D systems, trusses, 2-D problems, axis-symmetric solids, beams, frames, and some types of 3-D problems.

CE 402, Introduction to Transportation Engineering, 3 cr, 3 cl hrs

Overview of the field of Transportation Engineering. Topics covered include: description of transportation systems; traffic engineering studies; highway safety studies; traffic flow characteristics; transportation planning; travel demand; geometric design of highways; characteristics of drivers, pedestrians, vehicles, and roads and their applications to the determination of braking distance, stopping sight distance, passing sight distance, sign placement, and timing of change and clearance intervals.

CE 406, Design of Steel Structures, 3 cr, 3 cl hrs

Prerequisite: CE 302 or consent of instructor

Behavior and design of steel members subjected to tension, compression and flexural loads, according to AISC specifications. Topics covered include: elastic and inelastic design, buckling of beams and columns, and structural connections.

CE 407, Design of Concrete Structures, 3 cr, 3 cl hrs

Prerequisite: CE 302 or consent of instructor

Study of the strength, behavior and design of reinforced concrete members, including beams, columns and slabs. Topics covered will include serviceability of beams and slabs, control of deflections and cracking, shear design, and bonding.

CE 410, Reinforced Masonry and Timber Design, 3 cr, 3 cl hrs

Prerequisite: CE 302 or consent of instructor

Reinforced masonry design topics covered include: the properties and performance of masonry materials; design criteria and methods in reinforced masonry; and design examples including reinforced masonry walls, masonry columns and pilasters, and rectangular beams. Timber topics covered include: design of beams, columns, trusses, and diaphragms in wood; design of gluelaminated beams; design of wood connections; use of timber design codes and the International Building Code (IBC).

CE 412, Advanced Design of Steel Structures, 3 cr, 3 cl hrs

Prerequisite: CE 406 or consent of instructor

Behavior and design of structural steel beams, columns, frames, and connections. Topics include: elastic and inelastic design, composite beam design, stability of beams and columns, behavior of steel frame structures, design of bolted and welded connections, metallurgical and mechanical properties of welds, braced frame and moment frame design for lateral loads. Extensive use of the current AISC-LRFD design code.

CE 413, Foundation Design and Analysis, 3 cr, 3 cl hrs

Prerequisite: ME 420

Principles of soil mechanics and foundation engineering. Immediate and time dependent settlements, service loads, lateral loads, loading, approximate analysis methods, performance requirements, shallow foundations, lateral earth pressure, design of retaining walls, deep foundations, special footings, slope stability, and computer modeling of foundations. (Same as ME 413).

CE 414, Advanced Design of Concrete Structures, 3 cr, 3 cl hrs

Prerequisite: CE 407 or consent of instructor

Topics covered include: strut and tie models, footings, retaining walls, principles of prestressed concrete, materials and techniques used in these systems, advantages and disadvantages of prestressing methods over regular reinforced concrete, and the design of prestressed concrete structures, such as axially loaded members, beams (for flexure and shear), and slabs.

CE 418, Structural Dynamics, 3 cr, 3 cl hrs

Prerequisites: Math 335 and CE 302 or consent of instructor

Fundamentals of structural dynamics. Analysis of single and multi-degree-of-freedom structures subjected to various types of vibrations. Topics covered will include structural responses to free, harmonic and periodic excitations, step and pulse excitations, and earthquake loads.

CE 420, Pavement Materials and Design, 3 cr, 3 cl hrs

Prerequisites: CE 201 or ES 302

Analysis, behavior, performance, and structural design of pavements for highways, bridges and airfields. Topics include: climatic factors, maintenance strategies and life cycle design economics, traffic loadings, recycled pavement materials, evaluation by nondestructive testing (roughness, skid resistance, structural capacity), destructive testing, and rehabilitation of pavement systems.

CE 422, Geotechnical Waste Containment Design, 3 cr, 3 cl hrs

Prerequisites: ME 420; MATH 335

Design procedures consisting of waste disposal methods, various containment systems, and associated remediation techniques. Waste characterization and soil-waste interactions, contaminant transport in low permeability soils, geosynthetics and soil materials use in waste containment, remedial issues of solidification and stabilization and barrier design, and landfill- and surface impoundment-related design, including liners, leachate and gas collection and removal, final covers, static and seismic slope stability, and settlement analysis. Geotechnical problem definition, application of field and laboratory test data, use of computer models for analysis and design.

CE 423, Open Channel Hydraulics, 3 cr, 3 cl hrs

Prerequisites: ES 216

Analysis and characteristics of flow in natural and artificial open channel systems using energy, continuity, and momentum equations as applied to steady-state uniform, gradually varied, and rapidly varied flow profiles with emphasis on design of hydraulic structures. The students will use their knowledge of fluid mechanics, calculus, numerical analysis, and computer science to solve practical open channel flow problems. A variety of hydraulic conveyance and structures are covered, including rigid and flexible boundary channels, culverts, sluice gates, fumes, weirs, spillways, stilling basins, and bridges.

CE 481, Senior Engineering Design , 3 cr, 3 cl hrs

Prerequisite: Senior standing

A semester-long civil engineering design project organized and directed by a faculty member.

CE 491, Special Topics in Civil Engineering, 2-3 cr

Prerequisite: Senior standing or consent of instructor

New and developing areas of knowledge in civil engineering offered to augment the formal course offerings.

CE 518, Structural Dynamics, 3 cr, 3 cl hrs

Prerequisite: MATH 335 and CE 302 or consent of instructor

Fundamentals of structural dynamics. Analysis of single and multi-degree-of-freedom structures subjected to various types of vibrations. Topics covered will include structural responses to free, harmonic and periodic excitations, step and pulse excitations, and earthquake loads. Graduate students complete an additional project and a classroom presentation. Graduate work is graded separately. Lectures shared with CE 418.

Faculty Research Interests

Cook—Full-scale infrastructure destructive testing, bridge risk assessment (observed failures).

Ghosh—Macro behavior of composites, structural health monitoring and restoration

Hendrickx—Vadose zone hydrology, water and salt balance of natural and irrigated systems, evapotranspiration, remote sensing, soil physics, electromagnetic induction

Kuhn—Geotechnical engineering

McCord—Water resources engineering

McMullin—Structural engineering

Richardson—Biological wastewater treatment, environmental risk assessment, groundwater contamination, site remediation

Wilson—Structural vibration control, fuzzy control, earthquake engineering

Computer Science and Engineering

Professors Liebrock, Soliman

Associate Professors Mazumdar, Shin (Chair of the Department), Zheng

Assistant Professors Rezgui

Instructor Chadde

Adjunct Faculty Anselmo, Mukkamala, Clausen, Shipman

Emeritus Faculty Stavely, Sung

Degrees Offered: B.S., M.S., and Ph.D. in Computer Science; and M.S. in Computer Science with Information Technology Option

The Department of Computer Science and Engineering is focused on an exciting and rapidly growing body of knowledge with constantly changing emphasis.

The curriculum of the department includes courses in both theory and application. It prepares students to apply the principles of logic and mathematics to the design and construction of hardware and software systems using current engineering paradigms and also exposes them to major applications of computing.

The *Bachelor of Science in Computer Science* is accredited by the Computing Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore MD 21202-4012, telephone (410) 347-7700. The program emphasizes fundamental principles while striking a careful balance between the applications of computer technology and the theory of computing. In addition to the required fundamental computer science courses, students must also take technical electives to broaden their knowledge in major computer science application areas. Graduates of this program will be well prepared for both industry employment and graduate study.

Our graduate programs provide students the opportunity to take courses, select advisory committee members, and pursue research in an area of interest to a faculty supervisor. The *Master of Science in Computer Science* program is designed for students who wish to further broaden or deepen their knowledge of computer science and applications. Master's students usually participate in faculty research projects to complete their thesis or (non-thesis) independent study report.

New Mexico Tech's Department of Computer Science and Engineering also offers a *Ph.D. in Computer Science* program. The Ph.D. program is appropriate for students with motivation for research and either a superior track record in coursework or substantial experience in industrial research and development.

The department has been certified, since 2002, by the National Security Agency and the Department of Homeland Security as a National Center of Academic Excellence in Information Assurance Education. Since 2009, the department has also been certified as a National Center of Academic Excellence in Information Assurance Research.

The department has its own network of computers and servers plus a variety of other equipment in several laboratories. The Tech Computer Center supports a larger network that is also available to the department. Computing equipment at the research labs associated with Tech includes both symmetric multiprocessors and special purpose massively parallel computers. The department also has access to massively parallel machines at national laboratories and supercomputing centers.

Mission

Our mission is to produce computer science graduates who, trained in the design, implementation, and analysis of computational systems and skilled in technical communication, will contribute towards the advancement of computing science and technology.

Program Educational Objectives

Within a few years of graduating with a B.S. degree in Computer Science, our students will demonstrate that they have:

1. the ability to design, implement, and analyze computational systems;
2. the capability to tackle complex computer science related problems in the real world;
3. contributed towards the advancement of computing science and technology;
4. the capacity to work effectively with peers in computational tasks; and
5. cognizance of ethical, social, and legal issues pertaining to computer science.

Program Outcomes

The undergraduate academic program in Computer Science will enable our graduates to acquire by the time of their graduation:

- the ability to design, implement, and test small software programs, as well as large programming projects;
- knowledge of the theoretical concepts of computing;
- knowledge of the fundamental principles of programming languages, systems, and machine architectures;
- exposure to one or more computer science application areas;
- technical communication skills in written and oral form;
- the capacity to work as part of a team; and
- awareness of the legal, ethical, and societal impact of developments in the field of computer science.

Undergraduate Program

Bachelor of Science in Computer Science

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- CSE 101 (2), 113 (4), 122 (3), 213 (3), 221 (3), 222 (3), 241 (3), 324 (3), 325 (4), 326 (3), 331 (3), 342 (3), 344 (3), 353 (3), 382 (3), 423 (4)
- MATH 352 (3), 382 (3), 382L (1)
- Technical Electives: A sequence of 12 hours of CSE courses numbered 300 or higher, pre-approved by the student's advisor and the CSE Department, with no more than one course numbered CSE 485. Students are encouraged to select a coherent set of courses as technical electives that will prepare them for a specific focus in their career;
 - Each of the above courses must be completed with a grade of C or better.
 - General Electives to complete 130 credit hours.

Sample Curriculum 1 for the Bachelor of Science in Computer Science program

Semester 1 (Fall)

- 4 MATH 131 (calculus)
- 2 CSE 101 (introduction to comp science & info tech)
- 4 CSE 113 & 113L (introduction to programming)
- 3 ENGL 111 (college English)
- 13 Total credit hours

Semester 2 (Spring)

- 4 MATH 132 (calculus)
- 3 CSE 122 (algorithms and data structures)
- 4 CHEM 121 & 121L (general chemistry I)
- 3 ENGL 112 (college English)
- 14 Total credit hours

Semester 2.5 (Summer)

- 4 CHEM 122 & 122L (general chemistry II)
- 4 Total credit hours

Semester 3 (Fall)

- 3 CSE 221 (computer systems)
- 3 CSE 241 (foundations of computer science)
- 3 Humanities
- 5 PHYS 121 & 121L (general physics I)
- 3 ENGL 341 (technical writing)
- 17 Total credit hours

Semester 4 (Spring)

- 3 CSE 213 (intro to object oriented programming)
- 3 CSE 222 (systems programming)
- 3 Social Science
- 5 PHYS 122 & 122L (general physics II)
- 3 MATH 352 (basic concepts of mathematics)
- 17 Total credit hours

Semester 5 (Fall)

- 3 CSE 331 (computer architecture)
- 3 CSE 344 & 344L (design & analysis of algorithms)
- 3 Humanities
- 4 MATH 382 & 382L (probability and statistics)
- 3 Technical Electives
- 1 Electives
- 17 Total credit hours

Semester 6 (Spring)

- 3 CSE 326 (software engineering)
- 3 CSE 342 (formal languages and automata)
- 3 CSE 324 (principles of programming languages)
- 3 Technical Electives
- 4 Electives
- 16 Total credit hours

Semester 7 (Fall)

- 3 CSE 353 (data and computer communications)
- 4 CSE 423 & 423L (compiler writing)
- 3 Humanities/Social Science
- 3 Technical Electives
- 3 Social Science
- 16 Total credit hours

Semester 8 (Spring)

- 4 CSE 325 & 325L (operating systems)
- 3 CSE 382 (legal, ethical, social issues)
- 3 Humanities/Social Science
- 3 Technical Electives
- 3 Electives
- 16 Total credit hours

Sample Curriculum 2 for the Bachelor of Science in Computer Science program

Semester 1(Spring)

- 4 MATH 131 (calculus)
- 4 CSE 113 & 113L (introduction to programming)
- 3 ENGL 111 (college English)
- 4 CHEM 121 & 121L (general chemistry I)
- 15 Total credit hours

Semester 1.5 (Summer)

- 4 CHEM 122 & 122L (general chemistry II)
- 4 Total credit hours

Semester 2 (Fall)

- 4 MATH 132 (calculus)
- 2 CSE 101 (introduction to comp science & info tech)
- 3 CSE 122 (algorithms and data structures)
- 5 PHYS 121 & 121L (general physics I)
- 3 ENGL 112 (college English)
- 17 Total credit hours

Semester 3 (Spring)

- 3 CSE 213 (intro to object oriented programming)
- 3 CSE 222 (systems programming)
- 5 PHYS 122 & 122L (general physics II)
- 3 MATH 352 (basic concepts of mathematics)
- 3 Social Science
- 17 Total credit hours

Semester 4 (Fall)

- 3 CSE 221 (computer systems)
- 3 CSE 241 (foundations of computer science)
- 2 Electives
- 3 ENG 341 (technical writing)
- 3 Humanities
- 14 Total credit hours

Semester 5 (Spring)

- 3 CSE 324 (principles of programming languages)
- 3 CSE 326 (software engineering)
- 3 CSE 342 (formal languages and automata)
- 3 MATH 382 & 382L (probability and statistics)
- 3 Social Science
- 16 Total credit hours

Semester 6 (Fall)

- 3 CSE 331 (computer architecture)
- 3 CSE 344 & 344L (design and analysis of algorithms)
- 3 CSE 353 (data and computer communications)
- 3 Humanities
- 3 Technical Electives
- 15 Total credit hours

Semester 7 (Spring)

- 4 CSE 325 & 325L (operating systems)
- 3 CSE 382 (legal, ethical, social issues)
- 3 Humanities/Social Science
- 3 Technical Electives
- 3 Electives
- 16 Total credit hours

Semester 8 (Fall)

- 4 CSE 423 & 423L (compiler writing)
- 3 Technical Electives
- 3 Technical Electives
- 3 Humanities/Social Science
- 3 Electives
- 16 Total credit hours

Minor in Computer Science

Minimum credit hours required: 19

The following courses are required:

- CSE 113 (4) and CSE 122(3)
- Any four out of CSE 324 (3), CSE 325(4), CSE 326 (3), CSE 331(3), CSE 342(3), CSE 344(3), and CSE 353(3).
- Each of the above courses must be completed with a grade of C or better.

Graduate Program**Master of Science**

Students may earn a Master of Science degree in Computer Science or a Master of Science degree in Computer Science with the Information Technology Option through cooperation with the Information Technology faculty.

Master of Science Degree in Computer Science**Without Thesis:**

- 1.) Students must have demonstrated proficiency in the core undergraduate curriculum including the topics normally covered by CSE 324, 325, 331, 342, 344, and 423. Proof of proficiency usually requires grades of B or better in these courses or in equivalent courses approved by the department.
- 2.) Course work approved by the student's advisory committee fulfilling the general requirements of 27 credit hours for the master's degree. At least 15 credit hours must be in computer science courses numbered 500 or above, not including CSE 590 (Independent Study) or 591 (Thesis). Three of these hours must be CSE 585 (Graduate Seminar).
- 3.) CSE 590: 3 credit hours.

With Thesis:

- 1.) Students must have demonstrated proficiency in the core undergraduate curriculum including the topics normally covered by CSE 324, 325, 331, 342, 344, and 423. Proof of proficiency usually requires grades of B or better in these courses or in equivalent courses approved by the department.
- 2.) Course work approved by the student's advisory committee fulfilling the general requirements of 24 credit hours for the master's degree. At least 15 credit hours must be in computer science courses numbered 500 or above, not including 590 (Independent Study) or 591 (Thesis). Three of these hours must be CSE 585 (Graduate Seminar).
- 3.) CSE 591 (Thesis): 6 credit hours.

Master of Science Degree in Computer Science with Information Technology Option

Students earning a Master of Science degree in Computer Science can choose the Information Technology Option. The requirements for the Information Technology Option are the same as those for a Master of Science in Computer Science, except that:

Students must demonstrate proficiency in the topics normally covered by CSE 324, CSE 331, CSE 344, IT 321, IT 326, and IT 373. Proof of proficiency usually requires grades of B or better in these courses or in equivalent courses approved by the department.

Course work approved by the student's advisory committee fulfilling the general requirements of 24 credit hours (with thesis) or 27 credit hours (without thesis) for the master's degree. At least 15 credit hours must be in computer science courses numbered 500 or above, not including 590 (Independent Study) or 591 (Thesis). Three of these hours must be CSE 585 (Graduate Seminar). A minimum of 9 credit hours must be in a sequence of upper-division information technology courses approved by the student's advisory committee.

CSE 590 (Independent Study): 3 credit hours; or CSE 591 (Thesis): 6 credit hours.

There is no foreign language requirement for the Master of Science degree in Computer Science or the Master of Science degree in Computer Science with the Information Technology Option. The independent study or thesis topic may be selected, subject to approval from the student's advisory committee and the computer science chair (or information technology program coordinators), from any area of computer science or information technology.

Doctor of Philosophy in Computer Science

Students of exceptional ability as demonstrated in previous course work are encouraged to pursue a doctor of philosophy degree; individuals with substantial experience in industrial research and development may also apply to the doctoral program. The current research programs of the department include parallel computation, information assurance, high speed networks, neural networks, software engineering, verification, genetic algorithms, databases and knowledge-base systems, and computational intelligence. The department also encourages interdisciplinary work with other departments and divisions at Tech and in cooperation with researchers at Los Alamos and Sandia national laboratories.

As computer science and engineering is a diverse and rapidly changing discipline, the program of study of a Ph.D. student will depend on the area of specialization and on prior experience and education. All Ph.D. students will be required to demonstrate master's-level knowledge of the core areas of computer science, as well as a thorough understanding of the intended area of specialization. The core areas include systems (operating systems and computer architectures), programming (programming languages, compilers, data structures, and formal semantics), and theory (automata theory, algorithms, and computational complexity). In addition, all Ph.D. students are required to take three credit hours of CSE 585 (Graduate Seminar). The specific course requirements are determined with the consultation and approval of the student's advisory committee and the chair of the department.

The student must pass a preliminary examination in each of the core areas. A detailed list of topics to be covered is available from the department. The student must also pass a candidacy examination in his or her specific area of specialization. See the Graduate Catalog for further details.

Computer Science Courses:

In the following, each prerequisite requires a grade of C or better.

Some courses are marked 'cannot be used towards graduation' to emphasis that they cannot be used to fulfill the requirements for the major; they *can* be used as general electives to complete 130 credit hours.

CSE 101, Introduction to Computer Science and Information Technology, 2 cr, 2 cl hrs

Usually offered in both the Fall and Spring semesters.

Brief overview of the discipline of computer science and information technology topics including computer architecture, operating systems and networks, automata and models of computation, programming languages and compilers, algorithms, databases, security and information assurance, artificial intelligence, graphics, and social/ethical issues of computing. (Same as IT 101)

CSE 107, Introduction to Computer Programming using Python, 4 cr, 3 cl hrs, 2 lab hrs

Co-requisite: Math 103

Usually offered in the Fall semester.

The course is designed to introduce programming and its applications to scientists and engineers. The first part of the class focuses on problem solving, algorithm development, top-down design, modular programming, debugging, testing, data types, flow-control, looping, iteration and recursion, fundamental data structures, and an introduction to object oriented programming. The second part of the class explores data analysis with Python. (Same as IT 107)

CSE 113, Introduction to Programming, 4 cr, 3 cl hrs, 3 lab hrs

Co-requisite: MATH 131

Usually offered in both Fall and Spring semesters.

The course is designed to introduce problem solving and programming in C to Computer Science majors and those interested in applications of the language that involve dynamic structures and memory management. Topics include algorithm development; top-down design; modular programming; debugging; testing; control structures including selection, iteration and recursion; number systems; data representation; data types including arrays, strings, pointers and dynamic structures involving memory management. Concepts implemented through extensive programming using good programming style. (Same as IT 113.)

CSE 122, Algorithms and Data Structures, 3 cr, 3 cl hrs

Prerequisite: CSE 113 with a grade of C or higher

Corequisite: MATH 132

Usually offered in both Fall and Spring semesters.

Fundamental data structures including linked lists, trees, hash tables, and graphs. Algorithms for sorting, searching, and other fundamental operations. Introduction to mathematical foundations for analysis of iterative and recursive algorithms and for basic correctness proofs. Analysis of algorithms. Implementation of selected algorithms using sound programming methodologies. (Same as IT 122.)

CSE 209, Programming Language Practicum, 1 cr, 3 lab hrs

Prerequisite: Knowledge of elementary programming and CSE 101 with a grade of C or higher.

A practical course teaching the use of a programming language of current interest. May be repeated for credit with different languages.

CSE 213, Introduction to Object Oriented Programming, 3 cr, 3 cl hrs

Prerequisite: CSE 101, 113, 122 each with a grade of C or higher

Usually offered in the Spring semester.

Introduction to programming in an object oriented language (e.g., Java): review of problem solving, algorithm development, top-down design, modular programming, debugging, testing, control structures including selection, iteration and recursion, data types including arrays, strings, pointers, and dynamic structures. Object oriented concepts will include: objects, classes, inheritance, instances, methods, interfaces, packages, encapsulation, and polymorphism. Concepts implemented through extensive programming using good programming style. (Same as IT 213.)

CSE 221, Computer System Organization, 3 cr, 3 cl hrs

Prerequisite: CSE 101, 122 each with a grade of C or higher

Usually offered in the Fall semester.

The hardware/software interface. Basic organization of hardware and operating systems. Memories, buses, interrupts, input and output, and instruction set architecture. Programming in assembly language. (Same as IT 221.)

CSE 222, Systems Programming, 3 cr, 3 cl hrs

Prerequisite: CSE 101, 122 each with a grade of C or higher

Usually offered in the Spring semester

This course provides an introductory overview of operating systems and system programming, mainly focusing on system-level programming based on OS services and other APIs. Topics include system calls, file I/O, files and directories, memory management, process control, inter-process communication (IPC), socket-based network programming, remote procedure call (RPC) programming, and basic security mechanisms. Course work includes substantial programming homework and team-based projects.

CSE 241, Foundations of Computer Science, 3 cr, 3 cl hrs

Prerequisite: CSE 101, Math 132 each with a grade of C or higher

Usually offered in the Fall semester

Propositional and predicate logic. Analytic reasoning and mathematical proofs. Abstraction, iteration, recursion, and induction. Fundamental discrete structures. Basic concepts of algorithms, formal languages, and computation.

CSE 321, Internet and Web Programming, 3 cr, 3 cl hrs

Prerequisite: CSE 213, 221 each with a grade of C or higher

This course has a practical emphasis on the design and techniques for developing internet-based applications, mainly focusing on web programming. Topics include HTML, client-side scripting language (JavaScript), server-side programming (Servlets, JSP, and J2EE), and XML/web services (Java and .NET). This course will also cover some important topics needed for internet-based application developments, such as Internet architectures, basic object-oriented programming (OOP) concepts, and web security. Course work includes substantial programming homework and team-based projects. (Same as IT 321.)

CSE 324, Principles of Programming Languages, 3 cr, 3 cl hrs

Prerequisite: CSE 122 with a grade of C or higher

Co-requisite: CSE 213

Usually offered in the Spring semester.

Introduction to low (micro/macro) and high level languages (L/HLLs) -- features and positions within the computer system. definition of HLLs of syntax and semantics. Data types, control structures, concurrency, declarations, procedures. Recursion and recursive definitions. Procedural and data abstraction. Critique of major programming languages features and design issues (e.g., power, efficiency, security, modularity, readability, etc). Examples from major realms of current programming languages -- imperative (block structured, object oriented), declarative (function, logic) paradigms.

CSE 325, Principles of Operating Systems, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: CSE 221, 222 each with a grade of C or higher

Usually offered in the Spring semester.

Software I/O buffering. Discussion of concurrent processes, including mutual exclusion, synchronization, and deadlock. Processor scheduling, memory management, and resource control. Hoare's monitors. File systems. Each student is expected to design and implement a small operating system as a substantial portion of the course grade.

CSE 326, Software Engineering, 3 cr, 3 cl hrs

Prerequisites: CSE 122, 213 each with a grade of C or higher

Usually offered in the Spring semester.

This course provides the introductory overview of software engineering, concentrating on large-scale software system design and implementation. Topics include software life cycle, UML-based design language, design tools and techniques, design documentation, software testing, and software project management. Course work includes a team-based project. (Same as IT 326.)

CSE 328, Secure Software Construction, 3 cr, 2 cl hrs, 1 lab hr

Prerequisite: CSE 222, CSE 213 each with a grade of C or higher

Formal methods and practical techniques for the specification, design, implementation, and validation of computer software. Current software engineering and management practices, with emphasis on ensuring software reliability, safety, and security. Course work includes a team project to develop a sizeable, real-world application software. (Same as IT 328.)

CSE 331, Computer Architecture, 3 cr, 3 cl hrs

Prerequisite: CSE 221 with a grade of C or higher

Usually offered in the Fall semester.

Computer design fundamentals and hardware components: instruction set design, memory hierarchies, ALU's, control units, bus architectures, input and output, system design. Performance modeling and measurement.

CSE 342, Formal Languages and Automata, 3 cr, 3 cl hrs

Prerequisite: CSE 241; MATH 352 each with a grade of C or higher

Usually offered in the Spring semester.

Regular expressions. Regular, context-free, context-sensitive and unrestricted grammars and languages. Finite and pushdown automata. Turing machines, recursive and recursively enumerable languages. Decidability and the halting problem.

CSE 344, Design and Analysis of Algorithms, 3 cr, 3 cl hrs, 1 lab hr

Prerequisites: CSE 122, CSE 241; MATH 352 each with a grade of C or higher

Usually offered in the Fall semester.

Asymptotic complexity of algorithms. Analysis of iterative and recursive algorithms; amortized analysis. Design paradigms: greedy and dynamic programming approaches. Interplay of data structures and algorithms. Introduction to the theory of NP-completeness.

CSE 351, Modeling and Simulation Technologies for Information Systems, 3 cr, 3cl hrs

Prerequisites: CSE 122; CSE 241 each with a grade of C or higher

Fundamentals and techniques for designing and using simulation, modeling, and optimization algorithms with applications in system performance modeling, business infrastructure modeling, and distributed and parallel computing. An introduction to advanced complex systems models. (Same as IT 351.)

CSE 353, Introduction to Computer Networks, 3 cr, 3 cl hrs

Prerequisites: CSE 222 with a grade of C or higher

Usually offered fall semester

Introduction to computer networking, the ISO/OSI protocol stack, LAN, MAN, and WAN. Physical layer: transmission media (wireline and wireless); data signaling, modulation, and coding; multiplexing. Fiber optics networking technology: protocols & examples. Data link Layer: error/flow control— protocols design issues; MAC protocols for channel access and allocation. Wireless technology and protocols standards — IEEE 802.11 physical layer and MAC sublayer protocols. Network layer: subnet switching (CS/DG/VC) & routing protocols (Non/Adaptive); Congestion Control and QoS protocols. ISO vs. (TCP-UDP)/IP the Internet protocol stacks. Internet relays and protocols, e.g., routers, gateways, etc. Introduction to network security. Application layer protocols, E.G., DNS, E-mail, etc. (Same as IT 353.)

CSE 373, Introduction to Database Systems, 3 cr, 3 cl hrs

Prerequisite: CSE 122, CSE 241 each with a grade of C or higher

Conceptual modeling and database design using the entity-relationship model. The relational model; relational algebra and relational query languages; design theory for relational databases. Database integrity. Physical data organization. Introduction to problems of concurrency control, recovery, security, and distributed databases. Course work includes a project using SQL and the Oracle Database Management System. (Same as IT 373.)

CSE 382, 382D, Legal, Ethical, and Social Issues of Information Technology, 3 cr, 3 cl hrs

Prerequisite: CSE 326 with a grade of C or higher

Usually offered in both Fall and Spring semesters

A survey of current legal IT (and general business and management) issues. Social and ethical issues associated with IT and management of secure information systems. (Same as IT 382.)

CSE 391, Directed Study, cr and topics arranged**CSE 423, Compiler Writing, 4 cr, 3 cl hrs, 3 lab hrs**

Prerequisites: CSE 324, 326, 342, 344 each with a grade of C or higher

Corequisite: CSE 331

Usually offered in the Fall semester.

Implementation of compilers for higher level computer languages including: parsing, symbol table management, code emission, and code optimization. Each student implements a small compiler and designs an optimizing compiler as a substantial portion of the course grade. Individual and group projects. Practice in developing software requirement, specification, design, and test plan documents.

CSE 441, Cryptography and Applications, 3 cr, 3 cl hrs (Same as IT 441)

Prerequisites: CSE 122, CSE 241 each with a grade of C or higher

This course provides an introductory overview of modern cryptographic theory and techniques, mainly focusing on their application into real systems. Topics include number theory, probability and information theory, computational complexity, symmetric and asymmetric cryptosystems, one-way functions, block and stream ciphers, Kerberos authentication systems, public key infrastructure (PKI), secure socket layer/transport layer security (SSL/TLS), and cryptographic protocols/applications in many real systems. (Same as IT 441.)

CSE 451, 451D, Introduction to Parallel Processing, 3 cr, 3 cl hrs

Prerequisites: CSE 122 with a grade of C or higher

Introduction to supercomputers and massively-parallel machine architecture, models of parallel computation, parallel algorithms, synchronization, parallel languages, data and functional parallelism, parallel performance analysis, popular interfaces, and parallel debugging. Students will gain experience in parallelization of sequential algorithms and implementation of parallel algorithms. (Same as IT 451.)

CSE 452, 452D, Introduction to Sensor Networks, 4 cr, 3 cl hrs, 2 lab hrs

Prerequisites: CSE 325 and CSE 353 each with a C or higher, or consent of instructor

Introduction to sensory technology with special focus on wireless sensor networks (WSNs) applications, topologies, deployment, sensed data manipulation, mobile ad-hoc wireless communication, security. Low power consumption and data rates WSNs protocols (e.g., ZigBee/IEEE808.15.4). Students will get familiar with sensor nodes' hardware (motes and sensor boards) and programming (TinyOS and ZigBee application objects) via a set of practical lab/field experiments that covers the design, implementation, deployment, and data collection/analysis of some actual WSNs data/vent acquisition systems (e.g., environment monitoring, remote asynchronous event detection--forest fire, border intrusion, tsunami, earthquake, volcanic activities, etc).

CSE 453, Advances in Computer Networks and the Internet, 3 cr, 3 cl hrs

Prerequisite: CSE 353 with a grade of C or higher

In depth coverage of layering of protocols' stacks (ISOOSI and TCP/IP) and computer networks architectures, modern examples of LANs, MANs, WANs protocols/architectures. Recent developments in Fiber optics technology – protocols and architectures. High speed “all-fiber-optics” networks. Internetworking: global addresses/names and translation, virtual networks and tunnels, routing, subnetworks switching protocols, IPv6, multicasting. Mobile IP. End-to-end protocols, TCP and UDP. Advances in congestion control and resource allocation. Client-server models & applications. The QoS mechanism integrated/differentiated), ATM QoS. Network security: information and link security, encryption, internetworking security, IPsec, firewalls, VPN, wireless security. Analysis of networks protocols. (Same as IT 453.)

CSE 454, Computer Graphics, 3 cr, 3 cl hrs

Prerequisites: CSE 213, 222; MATH 254 each with a grade of C or higher

Design and implementation of visual interfaces. Graphics input and output hardware, display programming, 2-D transformations, approximation techniques for curve and surface representation. Introduction to the creation of 3-D computer-generated images, color theory, lighting and shading.

CSE 463, 463D, Information Assurance, 3 cr, 3 cl hrs

Prerequisite: Senior standing

Defense and offensive information warfare. Information system security. Computer break-ins, hacking, and other attack methods. Vulnerability and risk analysis. Theory and applications of cryptography. Intrusion detection and incident response. Security planning and management. (Same as IT 463.)

CSE 464, Introduction to Soft Computing, 3 cr, 3 cl hrs

Prerequisites: CSE 344; MATH 382 each with a grade of C or higher

Major types of artificial neural networks. Fuzzy logic theory and fuzzy systems construction. Genetic algorithms and evolutionary computing. Intelligent systems and engineering applications. Comparative study of the soft computing paradigm as a problem solving methodology.

CSE 476, 476D, Visualization, 3 cr, 3 cl hrs

Prerequisite: CSE 122 with a grade of C or higher, or consent of instructor

This course presents application of graphical visualization to current problems, with a focus on extracting and representing information in multidimensional data sets using 2D and 3D graphics. Topics include visualization tools and techniques, human vision and perception, color mapping, sound, data representation for insight extraction, time visualization, visual analytics, volume rendering, surface extraction and rendering. Students will develop visualizations of real world problems. (Same as IT 476.)

CSE 485, Undergraduate Seminar on Special Topics, 3 cr, 3 cl hrs

Prerequisite: Senior standing, one semester of upper division courses in computer science, and consent of the instructor
A research seminar for undergraduate students with a focus either on special topics in computer science or on the methodology and skills required for research in computer science. *Use as technical electives is limited (see requirements above), but may be taken multiple times as a general elective.*

CSE 489, 489D, Special Topics in Computer Science, 3 cr, 3 cl hrs

Prerequisites: CSE 213, 222 with a grade of C or higher and consent of instructor

Undergraduate special topics in computer science. For a list of recent offerings, please visit the department's website.

CSE 491, 491D, Directed Study, cr and topics arranged

Cannot be used toward graduation.

CSE 500, Directed Research, cr and topics arranged

This course may not be used to fulfill graduate degree requirements. Research under the guidance of a faculty member.

CSE 523, Advanced Compiler Writing, 3 cr, 3 cl hrs

Prerequisite: CSE 423 with a grade of C or higher

Advanced topics in compilation, such as theory of parsing, error recovery, optimization, semantics-directed translation, and hardware-independent and hardware-specific code generation.

CSE 525, Advanced Operating Systems, 3 cr, 3 cl hrs

Prerequisites: CSE 325 and 331 with a grade of C or higher or consent of instructor

Advanced topics in operating systems such as real-time, distributed systems, fault-tolerance, parallel I/O, performance, safety-critical systems, and verification.

CSE 528, Formal Methods in Software Development, 3 cr, 3 cl hrs

Prerequisites: CSE 342; CSE 325 or 328 or 423 with a grade of C or higher or equivalent experience

Use of mathematics, logic, and computer science theory in software development. Formal specifications; systematic development of programs from specifications. Correctness proofs and other analysis techniques.

CSE 531, Advanced Computer Architecture, 3 cr, 3 cl hrs

Prerequisite: CSE 331 with a grade of C or higher

Advanced topics in computer architecture.

CSE 532, Fault-Tolerant Computing, 3 cr, 3 cl hrs

Prerequisite: CSE 331 with a grade of C or higher, or consent of instructor

Techniques for design of fault-tolerant digital devices with on-line self-error-detection and self-error-correction. Fault-tolerant PLAs, gate arrays, and computer memories. Fault-tolerant computer architectures. Application of error-detecting and error-correcting codes for design of reliable devices with self-error detection/correction. Design of self-checking checkers. Combining on-line and off-line error-detecting techniques. Reliability analysis of fault-tolerant devices. Self-error detection/correction for multiprocessors.

CSE 542, Advanced Formal Language Theory, 3 cr, 3 cl hrs

Prerequisite: CSE 342 with a grade of C or higher

Extensive study of context-sensitive and recursively enumerable languages; closure properties, decidability, and ambiguity of various language classes. Special topics as time permits.

CSE 544, Analysis of Algorithms, 3 cr, 3 cl hrs

Prerequisite: CSE 344 with a grade of C or higher

Analysis of correctness and complexity of asymptotically efficient algorithms. Set partitioning, dominators of dags (with applications in code optimization), Strassen's matrix multiplication algorithm, FFT, Schonrage-Strassen integer multiplication algorithm, pattern matching, NP complete problems (both time and space), lower bounds. Discussion of problems for which no efficient algorithms exist.

CSE 546, Theory of Computation, 3 cr, 3 cl hrs

Prerequisite: CSE 342 with a grade of C or higher

Effective computability of functions and sets in terms of Turing machines and other computational models. Universal machines and examples of unsolvable problems. The Church-Turing thesis and formal proofs of the equivalence of Turing machines, systems of recursion equations, and other models of computation. Mathematical properties of the classes of recursive functions. Recursive and recursively enumerable sets.

CSE 551, 551D, Advanced Parallel Processing, 3 cr, 3 cl hrs

Prerequisite: CSE 451 with a grade of C or higher, or consent of instructor

This course focuses on the application of models of parallel computation, parallel algorithms, synchronization, parallel languages, parallel performance analysis, and parallel debugging to large problems and complex systems. Topics include: integrating data and shared memory parallelism, multilevel domain decompositions, portability, and scalability. Student will parallelize and analyze the performance of a complex system or application.

CSE 553, Advanced Computer Networks, 3 cr, 3 cl hrs

Prerequisite: CSE 453 with a grade of C or higher

Models of computer networks. Design and analysis issues. Abstract syntax notation, data compression, security and authentication. Recent developments in the field.

CSE 565, Neural Nets, 3 cr, 3 cl hrs

Prerequisites: CSE 344; MATH 254 and 382 with a grade of C or higher, or consent of instructor

Neuron modeling. The perceptron and multilayer perceptrons. Learning algorithms. The Kohonen model, the Grossberg model, the Hopfield model. Associative memory. Applications. Recent developments in the field.

CSE 567, Soft Computing, 3 cr, 3 cl hrs

Prerequisites: MATH 254, 382; CSE 344 or equivalent with a grade of C or higher, or consent of instructor

Artificial neural networks, with emphasis on multiplayer feedback networks, self-organizing networks, and Hopfield-style networks. Learning algorithms. Introduction to fuzzy systems and evolutionary computing. Engineering applications of soft computing. (Same as MENG 567: Smart Engineering Systems)

CSE 568, Intelligent Systems, 3 cr, 3 cl hrs

Prerequisites: MATH 254, 382; CSE 344 or equivalent with a grade of C or higher, or consent of instructor

Overview of the major paradigms of soft computing: neural networks, fuzzy systems, and evolutionary computing. In-depth coverage of selected topics in each area as relevant to intelligent systems. Recent advances in the field, and case studies of intelligent systems. Coursework includes a large-scale project. (Same as MENG 568: Smart Engineering Systems II)

CSE 569, Embedded Systems Design, 3 cr, 3 cl hrs

Prerequisite: consent of instructor

Hardware/software systems and codesign. Embedded processor architecture and programming. Models of computation for embedded systems. Behavioral design. OS primitives for concurrency, timeouts, scheduling, communication and synchronization. Architecture selection. Simulation, synthesis, and verification. Hardware/software implementation. Performance analysis and optimization. Application-level embedded system design concepts such as basic signal processing and feedback control. Design methodologies and tools. Design examples and case studies.

CSE 570, Real-Time Systems, 3 cr, 3 cl hrs

Prerequisite: consent of instructor

Classification of real-time systems. Fundamental theorems and corollaries of deadline and fixed priority real-time scheduling techniques. Schedulability analysis. Scheduling techniques to guarantee an array of timing requirements. Implementation of a set of tasks with periodic and aperiodic timing requirements. Execution time estimation of a piece of code. Modification of scheduling algorithms in a real-time kernel. Performance evaluation of an operating system for real-time applications.

CSE 573, 573D, Database and Knowledge-base Systems, 3 cr, 3 cl hrs

Prerequisites: CSE 373, CSE 241 with a grade of C or higher
Databases, object bases, and knowledge bases. Data models. Logical foundations of database and knowledge-base systems. Query optimization. Selected topics from current research.

CSE 576, 576D, Advanced Visualization, 3 cr, 3 cl hrs

Prerequisite: consent of instructor

This course presents application of graphical visualization to large problems and complex systems, with a focus on extracting and representing information in multidimensional data sets using 2D and 3D graphics. Topics include visualization tools and techniques, human vision and perception, color mapping, sound, data representation for insight extraction, time visualization, visual analytics, volume rendering, surface extraction and rendering. Students will perform visual analytics research for large problems and/or complex systems.

CSE 581, Directed Study, cr to be arranged**CSE 585, 585D, Graduate Seminar, 3 cr****CSE 589, 589D, Special Topics in Computer Science, 3 cr, 3 cl hrs**

Prerequisites: Two semesters of upper division courses in computer science and consent of instructor.

Graduate special topics in computer science. For a list of recent offerings, please visit the department's website.

CSE 590, Independent Study, cr to be arranged

Under the direction of a faculty member appointed by the department, the student shall prepare a paper making use of standard reference sources on some topics not covered by other course work.

CSE 591, Thesis (master's program), cr to be arranged**CSE 595, Dissertation (doctoral degree program), cr to be arranged**

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Faculty Research Interests

Anselmo—Strategic Management, Decision Theory, Risk Analysis

Clausen — Software Construction, Internet via Satellite, Multimedia/Internet Technologies, Embedded Systems

Liebrock—Computer Forensics, Information Assurance, Parallel Processing, Well Posedness Analysis, Visualization

Mazumdar—Mobile and distributed databases: Integrity, Privacy, Security; Information Systems, Software Integrity

Mukkamala—Information Assurance, Digital Forensics, Knowledge Mining, Applied Soft Computing Techniques, Bioinformatics, Information and Network Security Practices

Rezgui —Cloud Computing, Service-based computing, Energy-aware cellular networks

Shin— System security, Usable Security, Applied Cryptography, Software Engineering

Soliman—Computer Networks — fiber/wireless modern technologies and protocols, Sensor Networks — modern technologies and protocols, Computer/Sensor Networks Security, Programming Languages, Neural Networks — applications in image compression, cloud computing management, and sensor networks

Shipman — Lightweight Literate Programming, Technical Writing

Stavely—Formal Methods in Software Engineering, Programming Languages, Computational Logic
Sung—Computational Intelligence, Information Security, Bioinformatics

Zheng—Mobile Computing, Computer and Network security, Machine Learning and its Applications

Electrical Engineering

Professors Teare, Wedeward (Dean of Engineering)

Associate Professors Arechiga, El-Osery, Erives, Jorgensen

Assistant Professor Senay

Emeritus Professor Bond

Adjunct Faculty Andrews, Elias, Helmboldt, Kassim, Mansfield,

Meason, Patamia, Prager, Restaino, Wick, Wilber, Xiao

Degrees Offered: B.S. in Electrical Engineering; M.S. in Electrical Engineering

Mission

The mission of the New Mexico Tech Electrical Engineering Department is two-fold: (1) to develop and maintain a program of excellence in teaching which ensures that our graduates have technical knowledge and professional skills they need to become effective engineers in the rapidly-changing technical environment of today's society, so that these graduates will contribute to the growth and development of New Mexico and our nation, and (2) to develop and maintain state-of-the-art research programs which are responsive to the needs of industry and government, which provide excellent educational opportunities for students, and which provide an environment for intellectual growth and excitement.

Program Educational Objectives for Undergraduate Program in Electrical Engineering

The faculty of the Department of Electrical Engineering strives to continuously improve the undergraduate program in electrical engineering. The educational objectives reflect the needs of, and have been reviewed by, among others, the Advisory Board and faculty. Several years after graduation it is expected that the program's graduates will be:

- recognized leaders in electrical engineering-related fields or other career paths, in the public and private sectors;
- valued leaders and participants in diverse teams who boldly discover and apply new knowledge and engineering practices;
- adaptive learners who continue to grow professionally in their organizations, or by earning post-graduate degrees.

Student Outcomes for Undergraduate Program in Electrical Engineering

Upon graduation with the degree of Bachelor of Science in Electrical Engineering, students will have obtained:

- an ability to apply knowledge of mathematics, science, and engineering;
- an ability to design and conduct experiments, as well as to analyze and interpret data;
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

- an ability to function on multidisciplinary teams;
- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- a recognition of the need for, and an ability to engage in life-long learning;
- a knowledge of contemporary issues;
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Undergraduate Program

The Department of Electrical Engineering concentrates on a high-quality undergraduate program in electronics and design, combined with a firm intellectual foundation in the fundamentals of circuits, signals, and systems. As with other degree programs at New Mexico Tech, students are also provided with a breadth of knowledge in the basic sciences, mathematics, humanities, and social sciences.

Laboratories constitute an important part of the electrical engineering program. The laboratories are closely coupled with the lecture parts of courses and utilize modern, state-of-the-art equipment. Computer-based instruments and software packages provide students with up-to-date engineering and design techniques.

Engineering design is the iterative process of converting a set of needs into a process, system or component. Students learn to combine the tools of basic sciences, mathematics and engineering sciences to meet requirements using a process of establishing objectives and criteria, analysis, construction, test and evaluation. Three courses are strongly focused on the fundamentals of engineering design in which students apply understanding from previous courses to solve real-world problems. Projects for the final design courses change every year, and past contributors of projects include research laboratories at New Mexico Tech such as Langmuir Laboratory for Atmospheric Research, Energetic Materials Research and Testing Center, Etscorn Observatory, and those of individual professors; national organizations such as the VLA and VLBA facilities of the National Radio Astronomy Observatory, Sandia National Laboratories, Los Alamos National Laboratory, Air Force Research Laboratory, and Naval Research Laboratory; and companies such as Microsoft and National Instruments.

Graduates of the electrical engineering program will be well equipped with the practical skills necessary for immediate employment, as well as with the intellectual base for graduate studies and lifelong learning.

Bachelor of Science in Electrical Engineering

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

Electrical Engineering core: EE 101 (2), EE 211 (3) or ES 332 (3), EE 212 (4), EE 231 (4), EE 308 (4), EE 321 (4), EE 333 (3), EE 341 (3), EE 382 (3), EE 434 (3), EE 451 (4), EE 481 & 481L (3), EE 482 & 482L (3)

Introduction to problem-solving and computer skills: EE 251 (4) or CSE 113 (4)

Mathematics core: MATH 231 (4), 254 (3), 335 (3), 382 (3), upper-level (300-level and above) mathematics elective (3)

Electrical Engineering electives: a minimum of eight credit hours, including at least one lab credit hour, from Electrical Engineering 300- and 400-level courses, excluding the Electrical Engineering core classes listed above.

Engineering electives: Six hours of engineering courses numbered 200 and above. Courses from Electrical Engineering may not be used to satisfy this requirement.

To enroll in an Electrical Engineering class, a student must have passed the prerequisites of the course. In addition, a student must be in good academic standing and have declared electrical engineering as a major to enroll in EE 382 and EE 481.

Students pursuing a B.S. degree in Electrical Engineering must take all Electrical Engineering courses for a letter grade.

Sample Curriculum for the Bachelor of Science in Electrical Engineering

Semester 1

4 MATH 131 (calculus I)
5 PHYS 121 & 121L (general physics I)
2 EE 101 (introduction to electrical engineering)
3 ENGL 111 (college writing)*
14 Total credit hours

Semester 2

4 MATH 132 (calculus II)
5 PHYS 122 & 122L (general physics II)
4 CHEM 121 & 121L (general chemistry I)*
4 EE 251 or CSE 113 (programming)
17 Total credit hours

Semester 3

4 MATH 231 (calculus III)
4 CHEM 122 & 122L (general chemistry II)*
3 EE 211 (circuits I)
4 EE 231 (digital electronics)
3 ENGL 112 (college writing)*
18 Total credit hours

Semester 4

3 MATH 254 (linear algebra)
3 MATH 335 (differential equations)
4 EE 212 (circuits II)
4 EE 308 (microcontrollers)
3 Social Science*
17 Total credit hours

Semester 5

4 EE 321 analog electronics)
3 EE 333 (electricity and magnetism)
3 EE 341 (signals and linear systems)
3 ENGL 341 (technical writing)*
3 Mathematics Elective (upper-level)
16 Total credit hours

Semester 6

3 EE 382 (introduction to design)
3 EE 434 (electromagnetic wave transmission/radiation)
3 MATH 382 (probability and statistics)
4 Electrical Engineering Elective with lab
3 Social Science*
16 Total credit hours

Semester 7

3 EE 481 & 481L (senior design project I)
4 EE 451 (digital signal processing)
4 Electrical Engineering Elective
3 Humanities*
3 Humanities or Social Science*
17 Total credit hours

Semester 8

3 EE 482 & 482L (senior design project II)
6 Engineering Elective
3 Humanities or Social Science*
3 Humanities*
15 Total credit hours

* These courses are requirements for the general education core curriculum, but are not pre- or co-requisites for courses in electrical engineering. Students are encouraged to work with their academic advisors to find suitable points of inclusion in the course program.

Minor in Electrical Engineering

Minimum credit hours required—19

The following courses are required:

- EE 101 (2), EE 211 or ES 332 (3), EE 212 (4), EE 231(4)
- Six (6) additional credit hours of Electrical Engineering courses selected from: EE 308 (4), EE 321 (4), EE 322 (4), EE 324 (3), EE 333(3), EE 341 (3).

Graduate Program

Educational Objectives for Graduate Program in Electrical Engineering

The faculty of the Department of Electrical Engineering strives to continuously improve the graduate program in electrical engineering. The educational objectives reflect the needs of, and have been reviewed by, among others, the Advisory Board and faculty. Several years after graduation it is expected that our graduates will be:

- technology leaders who fearlessly discover, apply and teach new knowledge and engineering practices;
- entrepreneurially minded innovators driving positive economic and social impact in their communities and the nation;
- adaptive learners who continue to grow educationally and professionally through advancing their education.

Student Outcomes for Graduate Program in Electrical Engineering

To achieve the general goals of the Department of Electrical Engineering, student outcomes reflect the needs of, and have been reviewed by, among others, the Advisory Board and faculty. Upon graduation with the degree of Master of Science in Electrical Engineering, students will have obtained:

- an ability to apply methods of advanced analysis appropriate for professionals to use when solving problems;
- an ability to apply an in-depth knowledge in a particular field of study that supports the use of innovative techniques to solve problems;
- an ability to demonstrate skills pertinent to the research process, including the ability to formulate problems, synthesize and integrate information, work collaboratively, communicate effectively, and publish results (MS thesis students).

Master of Science in Electrical Engineering

The Electrical Engineering graduate program provides students with unique research opportunities, thanks to its close association with many research facilities. These facilities include Energetic Materials Research and Testing Center, Langmuir Laboratory, Magdalena Ridge Observatory, National Radio Astronomy Observatory, Incorporated Research Institutions for Seismology, and Institute for Complex Additive Systems Analysis; all easily accessible from campus. These facilities can provide opportunities for students to participate in research related to leading scientific and engineering projects and allow them to achieve highly desirable educational and research experiences.

The student's course of study must be approved by the student's advisory committee, must fulfill the general requirements for the master's degree (page 8), and must include any two of the following courses:

- EE 521, Measurement and Instrumentation
- EE 531, Advanced Digital Design
- EE 544, Modern Control Systems
- EE 554, Embedded Control Systems
- EE 570, Advanced Topics in Electrical Engineering

At least 12 semester hours must be approved Electrical Engineering courses. No more than six (6) semester hours of advanced undergraduate course work may be used to satisfy the degree requirements. Students are required to take at least six (6) credit hours from outside the Electrical Engineering department. Students may choose between an M.S. with thesis (24 credit hours of courses plus six (6) thesis hours) or an M.S. with independent study (27 credit hours of courses plus three (3) independent study hours). Students may be required to take an appropriate software course if they don't have an appropriate programming background.

A five-year B.S./M.S. Electrical Engineering degree can be achieved by fulfilling the separate requirements of both an undergraduate degree and a graduate degree in Electrical Engineering in a five-year period. A combined minimum of 158 credit hours with at least 19 credit hours of 500-level courses and Independent Study (EE 590) is required. Students in the Electrical Engineering five-year program must normally apply for graduate standing at the end of their seventh semester. Graduate admission will be contingent upon adherence to the approved program of studies. Graduate status will be granted on fulfillment of the requirements for the B.S. Degree.

Sample Curriculum for the Master of Science in Electrical Engineering with Thesis

Semester 1

4 EE 521 (measurement and instrumentation)
 4 EE 554 (embedded control systems)
 3 Non-EE Course
 11 Total credit hours

Semester 2

4 EE 570 (advanced topics)
 3 EE 581 (directed study)
 3 Non-EE Course
 10 Total credit hours

Semester 3

6 EE 591 (thesis)
 3 Graduate Elective
 9 Total credit hours

Graduate Certificate in Electrical Engineering

The Electrical Engineering graduate certificate program is aimed at practicing engineers wanting to increase their exposure to electrical engineering at the graduate level while not being tied to a degree program. The program is designed to provide a rigorous upgrade to the student's skills in electrical engineering while focusing on topics of interest to the student.

The certificate program requires a minimum of 16 credit hours of graduate course work. The course requirements are: EE 521 Measurement and Instrumentation (4 credits)

One 4 credit electrical engineering graduate course

One 3 credit or higher electrical engineering course at either graduate or upper undergraduate level.

One 3 credit or higher graduate course in either mathematics, physics, engineering or computer science.

EE 590 Independent Study (2 credits) supervised by a member of the electrical engineering department.

Electrical Engineering Courses:

The Department of Electrical Engineering encourages students from other majors to take electrical engineering courses. Students from other disciplines who are interested in taking electrical engineering courses should inquire at the department office.

EE 101, Introduction to Electrical Engineering 2 cr, 1 cl hr, 3 lab hrs

Corequisite: MATH 103

Normally offered fall and spring semesters

A broad overview of electrical engineering, including an introduction to analog and digital circuitry. Practical exercises using the EE department's computer-based applications software and lab equipment.

EE 211, Circuits and Signals I, 3 cr, 3 cl hrs

Prerequisites: MATH 132; EE 101 or junior standing

Normally offered fall semester

Principles of electrical circuit analysis. Kirchhoff's laws, equivalent circuits, dependent sources, node and mesh analyses, signals, RLC components. Introductory circuits and operational amplifier circuits as examples.

EE 212, Circuits and Signals II, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 211 or ES 332

Normally offered spring semester

Continuation of EE 211, Laplace transform techniques, transient response, power, steady-state sinusoidal response, and frequency response of RLC circuits.

EE 231, Digital Electronics, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 101

Corequisites: EE 251 or CSE 113

Normally offered fall semester

Foundation of combinational digital system analysis and design; including Boolean algebra, logic gates, and truth tables. Sequential digital design via finite state machines. Lab provides exposure to computer-aided design software and programmable logic hardware.

EE 251, Mathematical Engineering, 4 cr, 3 cl hrs, 3 lab hrs

Corequisite: MATH 103

Normally offered fall semester

Standard programming languages in engineering are applied to data acquisition, data analysis, and mathematical computations. Fundamental concepts in Matlab and C are used to develop programming skills and techniques by addressing problems related to electrical engineering. Typical topics include programming hardware; collection and manipulation of large data sets; signal and noise analysis; data fitting; numerical solutions to problems; basics of image processing; data encryption; steganography; and signal acquisition and extraction using Matlab toolboxes with commonly available hardware.

EE 308, Microcontrollers, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 231

Normally offered spring semester

Introduction to microcontrollers. Elementary assembly- and C-language programming, bus structures, parallel and serial interfaces, support devices. Use of logic analyzers and disassemblers in circuit testing. Use of microcontrollers in measurement and control applications.

EE 321, Analog Electronics, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 212

Normally offered fall semester

Basic principles and use of operational amplifiers, diodes, field-effect transistors, and bipolar junction transistors in electronic circuits.

EE 322, Advanced Electronics, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EE 321 and EE 341

Applications in analog electronics. Topics include timing and switching circuits, power supply techniques, active filters, switched capacitor circuits, oscillators, and phase-locked loops.

EE 324, Semiconductor Theory and Devices, 3 cr, 3 cl hrs*Prerequisite: PHYS 122*

Fundamentals of semiconductor materials and devices. Topics include introduction to quantum mechanics and electrical conduction in conductors, insulators, and semiconductors. The theory is applied to pn junctions, bipolar and field-effect transistors and opto-electronic devices.

EE 333, Electricity and Magnetism, 3 cr, 3 cl hrs*Prerequisite: PHYS 122 and MATH 231**Normally offered fall semester*

Electric and magnetic fields in free space and in matter. Energy storage as a function of field quantities and the relation of this to capacitance and inductance. Maxwell's equations applied to simple electrostatic and magnetostatic problems, plane waves, and transmission lines. Transient and sinusoidal steady state solutions of uniform transmission line problems modeled in terms of circuit parameters.

EE 341, Signals and Linear Systems, 3 cr, 3 cl hrs*Prerequisites: EE 212 and MATH 335**Normally offered fall semester*

Principles of linear time-invariant systems. Dynamic systems, Laplace transforms, z-transforms, sampling theory, system functions, poles and zeros, frequency domain, Fourier Transforms, feedback systems, convolution.

EE 352, Microcomputer Interfacing, 4 cr, 3 cl hrs, 3 lab hrs*Prerequisites: EE 308*

Design of hardware and software for microcomputer interfacing. Bus signals and timing. Interrupt and direct memory access handling. Students will design, build, program, and test a simple interface card for a common microcomputer bus.

EE 382, Introduction to Design, 3 cr*Prerequisites: EE 308, 321, 333, 341, and have declared electrical engineering as a major**Normally offered spring semester*

A course in design methodology as applied to a particular problem in electrical engineering. For a given project, students will integrate their formal course work with the use of computer-aided tools to design, construct, evaluate, and document a prototype system.

EE 408, Cooperative Education

On-the-job training to supplement the academic program. Students alternate periods (usually six months long) of full-time semiprofessional employment in Electrical Engineering with periods of full-time academic study. A written report of the student's activities will be required at the end of the training.

EE 434, Electromagnetic Wave Transmission and Radiation, 3 cr, 3 cl hrs*Prerequisite: EE 333**Normally offered spring semester*

Reflection and refraction of plane waves at planar interfaces. The propagation characteristics of metallic and dielectric waveguides with particular emphasis on fiber optics. Radiation from linear current elements and planar apertures and arrays of these elements. Analysis of simple communication links.

EE 435L, RF and Microwave Laboratory, 1 cr, 3 lab hrs*Corequisite: EE 434*

Experiments in radio frequency and microwave techniques and measurements.

EE 443, Intermediate Control Theory, 3 cr, 3 cl hrs*Prerequisite: EE 341*

Modeling of dynamical systems via differential equations, transfer functions, and state-space methods. Performance, characterization, and behavior of linear feedback-systems. Design of various types of control schemes to meet performance specifications.

EE 443L, Intermediate Control Theory Lab, 1 cr, 3 cl hrs*Corequisite: EE 443 or MENG 405 or permission of instructor*

Use of computer-based data acquisition and control (DAC) hardware and software. Model validation and verification of physical systems. Implementation of real-time control schemes utilizing actuators and sensors.

EE 446, Introduction to Communications Theory, 3 cr, 3 cl hrs*Prerequisites: EE 341 and MATH 382*

Principles of communication theory. Modulation techniques, random signals and noise, analysis of communication systems in presence of noise, digital communication, matched filters, channel capacity, multiple access.

EE 451, Digital Signal Processing, 4 cr, 3 cl hrs, 3 lab hrs*Prerequisites: EE 308 and EE 341**Normally offered fall semester*

Principles of digital signal processing. Infinite and finite impulse response filters, discrete and fast Fourier transforms, multirate processing, spectral estimation, quantization effects, system design. Implementation of real-time DSP algorithms on state-of-the-art hardware. Principles discussed in class will be demonstrated with real applications. Labs include design and implementation of infinite and finite impulse response filters, and applications such as communication systems, sound processing, and image processing.

EE 481, 481L, Senior Design Project I, 3 cr

Prerequisites: EE 382, and have declared electrical engineering as a major

Normally offered fall semester

Student design teams begin an academic year long capstone design project under the supervision of a faculty advisor. Each team may undertake a different project and will build a team, determine design requirements, perform detailed planning, identify project needs and establish goals leading toward the successful completion of the project. Periodic design reviews and reports, applications of engineering skills, project management and formal presentations are major components of the program. Successful completion of the project requires the application of electronics, applied physics, numerical computation, signal processing and other electrical engineering techniques to real-world engineering problems.

EE 482, 482L, Senior Design Project II, 3 cr

Prerequisites: EE 481, and have declared electrical engineering as a major

Normally offered spring semester

A continuation of the capstone design projects started in EE 481. EE 482 must be taken in the semester immediately following EE 481, 481L to maintain project continuity. The student teams bring their design projects to successful conclusion. Status reports, a final presentation to faculty and reviewers and the submission of a senior thesis are included in the program.

EE 491, Special Topics, hrs and crs to be arranged**EE 500, Directed Research, cr to be arranged**

Prerequisite: Graduate standing

Offered both Spring and Fall semester. Credits cannot be applied towards the 30 credit hours required for graduation. Research under the guidance of an EE faculty member.

EE 521, Measurement and Instrumentation, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EE 308, 322, 341 or equivalent or consent of instructor

Survey of various sensors and transducers for measuring physical quantities; measurement errors; analog and digital interfaces; sampling; quantization; actuators; and sensing devices in closed-loop control. Digital interfacing to the measurement devices for both experimentation and microprocessor control will be performed using a computer equipped with data acquisition hardware and software.

EE 531, Advanced Digital Design: 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 231 or equivalent or consent of instructor

Advanced topics in digital design. Synchronous and asynchronous state machines. Timing issues in high-speed digital design. Design of a complex system using Verilog or VHDL programming language in a CAD environment.

EE 533, Optical/RF Engineering, 3 cr, 3 cl hrs

Prerequisites: EE 324, 434 or equivalent or consent of instructor

Explore various topics in data links and telemetry including RF links, antennas, satellite communications, and optical fiber links. Projects will include design and fabrication of basic RF antenna and a case study of a satellite communications system.

EE 537, Photonics, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: Graduate standing; EE 434; or consent of instructor

Topics include the generation, propagation, manipulation and detection of light from low to high energy. Uses and applications of optical systems: simple optics, binary and Fourier optics, electro-optics, wavefront analysis, modal decomposition, inversion techniques for wavefront reconstruction and correction and optical signal processing. Other advanced topics in optics.

EE 544, Modern Control Theory, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EE 443; MATH 454; or equivalent or consent of instructor

Treatment of modern approach to control system design primarily via state-space analysis techniques for both continuous and discrete time systems. Topics include the realization of MIMO models for real-systems, linear feedback control, the design of observers, optimal control, and concepts in stability. The latter part of the course will address recent advanced topics of current relevance. Associated hardware and software-based lab/project(s) will include the use of computer-based data acquisition systems.

EE 545, Digital Communication I, 3 cr, 3 cl hrs

Prerequisite: EE 446 or equivalent or consent of instructor

Digital communication systems; response time requirements and control of user errors. Spread spectrum modulation and the fundamental limitations dictated by information theory. Various types of modulation and multiplexing including BPSK, QAM, QPSK, OQPSK. Statistical analysis of various modulation schemes.

EE 546, Digital Communication II, 3 cr, 3 cl hrs

Prerequisite: EE 545 or consent of instructor

Spread-spectrum modulation, frequency hopping techniques, error control coding, multiple access techniques including TDMA (time division multiple access) and CDMA (code division multiple access). Various advanced case studies. Analysis of imperfections; noise and distortion line failures, data errors, delays and blocking, treatment of errors.

EE 548, Manipulator-based Robotics: 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 443 or equivalent or consent of instructor

Fundamentals of the multi-disciplinary field of robotics. Emphasis is placed on understanding how to model and control robotic manipulators while providing an appreciation of the importance of sensing to robotic applications. Topics include: forward, inverse, and motion kinematics; dynamic modeling; position, velocity, and force control.

EE 551, Discrete-Time Signal Processing, Filtering, and Estimation, 3 cr, 3 cl hrs

Prerequisites: EE 451; MATH 254, 382; or consent of instructor

The fast-Fourier transform and its computer implementation; spectral estimation; analytic signals; multi-dimensional signal processing; digital filters. Signal detection and estimation, Kalman Filters, linear predictive coding, and adaptive filters. Project(s) include the design and implementation of a Kalman filter for GPS data processing and LPC for speech recognition.

EE 552, Image Processing and Data Compression Techniques, 3 cr, 3 cl hrs

Prerequisites: EE 451; MATH 254, 382; or consent of instructor

The basics of two-dimensional digital signal processing, image representation and human vision including color models, image transformation and video compression techniques (including JPEG and MPEG). Study of relevant current applications including HDTV.

EE 554, Embedded Control Systems, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EE 308, 443 or equivalent or consent of instructor

Microcontroller- or microcomputer-based embedded control systems. A comparative survey of currently available embedded computers/controllers including SBC's, PICs, basic-stamps, and System on Chip (SoC) solutions. Real-time operating systems, including real-time LINUX, and hard real-time process requirements. Projects will include the implementation of an embedded real-time control solution.

EE 562, Microwave Engineering & Radar, 3 cr, 3 cl hrs

Prerequisite: EE 434 or equivalent or consent of instructor

Transmission media: waveguides, micro-strip and glass fiber. Ferrite devices and cavity resonators. Equivalent circuits using scattering and transmission matrices. Active components in microwave circuits.

EE 569, Wireless Communications, 3 cr, 3 cl hrs

Prerequisite: EE 446 or equivalent courses or consent of instructor

Signaling: exchange, subscriber loops, and local loops, transmission media, and multiplexing. Switching: network switching, space-division and panel switching, and various digital-switching methods. Cellular telephony, data networks and communication protocols.

EE 570, Advanced Topics in Electrical Engineering, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: EE 333 or equivalent or consent of instructor

Emerging technologies and specializations in Electrical Engineering addressed from the perspective of embedded systems and advanced design.

EE 581, Directed Study, cr to be arranged

Prerequisite: Permission of graduate advisor

EE 590, Independent Study, cr to be arranged

Prerequisite: Permission of graduate advisor

Independent research supervised by a faculty member. It is expected that this work will culminate in a paper to be published, and an oral presentation is required.

EE 591, Thesis (Master's Program), cr to be arranged**EE 592, Graduate Seminar, 1 cr, 1 cl hr**

Prerequisite: Graduate standing

Offered both Spring and Fall semester. Credits cannot be applied towards the 30 credit hours required for graduation.

Faculty Research Interests

Andrews—Optoelectronics, Experimental Adaptive Optics, Imaging Systems
 Arechiga—Speech Processing, Thunderstorms
 Bond—Design for Test/Manufacturability, Teaching Effectiveness
 Elias—Ionospheric Research, Optical Interferometry, Astronomical Photon Orbital Angular Momentum
 El-Osery—Wireless Communications, Control Systems, Soft Computing
 Erives—Hyperspectral Imaging, Sound Processing, Embedded Control Systems
 Helmboldt—Novel Applications of Radio Astronomy Instrumentation
 Jorgensen—Spacecraft and Astronomical Instrumentation, Space Physics, Data Assimilation, Sensor Networks, Space Elevators
 Kassim—Novel Applications of Radio Astronomy Instrumentation
 Mansfield—Communications, Radio Frequency (RF) Systems
 Meason—Nuclear, Electromagnetic and Space Radiation Effects, Directed Energy
 Patamia—Analytical and Numerical Modeling, Space Elevators
 Prager—Semiconductors
 Restaino—Adaptive Optics, Novel Optical Systems
 Senay—Communications, Signal Processing, Control Systems
 Teare—Adaptive Optics, Smart Sensors, Ballistics, Energetic Materials
 Wedeward—Control Systems, Robotic Systems, Electric Power Systems
 Wick—Experimental Adaptive and Active Optics
 Wilber—Electronic Countermeasures, Energetic Materials
 Xiao—Photonic/Fiber Sensors

Engineering Management

Professors Sueyoshi

Associate Professors Anselmo, Reinow (Chair of the Department), Yuan

Adjunct Faculty: Mazumdar, Ostergren, Peterson

Degree offered: Master of Engineering Management

The New Mexico Tech Master of Engineering Management (MEM) graduate program is designed to provide working engineers and applied scientists with a terminal degree in Engineering Management. The curriculum is designed to be innovative and deliverable both on campus and in other areas of New Mexico live via interactive webcasts and everywhere else via Internet streaming. Qualified students at any location may enroll and receive the program through the Internet and/or mailed copies of lectures and course materials. New Mexico Tech developed the Engineering Management program since most engineers eventually have the opportunity to become managers, and many undergraduate engineering and applied science programs do very little to prepare their graduates for that career event.

Graduate Program

Master of Engineering Management (MEM)

Admission to the Program

Entrance into the MEM program in the New Mexico Tech Management Department requires competence in engineering, science and mathematics comparable to a calculus-based bachelor of science degree in an engineering or applied science discipline. Preference for limited program slots will be given to individuals with at least 2 years work experience in either engineering or applied science. A committee of New Mexico Tech Management and Engineering faculty will evaluate program applicants, and the Management Department chair will review and finalize committee recommendations. Each student is responsible for forming a graduate committee during the first semester of full-time study or before the end of the second semester of part-time coursework.

For complete information on applying to the MEM Program, see the Graduate Catalog.

Graduate Advisory Committee

Participants will form a three-member committee that will be composed of at least one New Mexico Tech faculty member and two other qualified individuals. Examples of qualified individuals include faculty members at New Mexico Tech, faculty members at other higher-education institutions, workplace supervisors, and/or professional peers. In the case where there is only one committee member from the New Mexico Tech faculty, that individual will serve as committee chair. If there are more than one New Mexico Tech faculty members on the student's project committee, the student will select a chair.

The primary roles of the committee will be to assist the student in selection of an elective sequence and to advise and approve the required final project.

Program Requirements

A total of 30 credit hours, including the following courses, is required for the MEM degree:

- Core (21): EMGT 501 (3), 502 (3), 503 (3), 505 (3), 506(3), 507 (3); EMGT 504 (3) or MATH 585 (3)
- Electives (6): Example sequences are EMGT 511 (3) and 512 (3) or EMGT 521 (3) and 522 (3). Other sequences are possible and should be selected in consultation with the student's academic advisor.
- EMGT 590 (3)

The purpose of the core is to provide foundations in quantitative and qualitative methods that will assist the practicing (or aspiring-to-practice) engineer in a changing technological and economic environment. The core is designed for engineers and is grounded in the notion that program participants possess the analytical skills associated with a calculus-based undergraduate bachelor of science in engineering.

The minimum of six (6) hours of electives will assist program participants to gain expertise in an area of interest and relevance to their careers. These two courses should be taken as a sequence, and participants may select their sequence after consulting with their faculty advisor(s). The elective sequence may be any approved graduate elective sequence from graduate coursework offered at New Mexico Tech. Students considering elective sequences from other graduate institutions may do in consultation with their New Mexico Tech graduate committee.

The terminal MEM requirement is a final project, culminating in a formal document and presentation to the faculty that is analogous to the Independent Study option currently available to graduate students at New Mexico Tech. Participants will benefit from designing, supervising, and executing a project that will ideally be a workplace application. This experience will aid them throughout their careers as they are faced with the need to resolve critical strategic questions and implement recommended solutions.

Engineering Management Courses

In addition to the listed prerequisites, only students admitted to the MEM program may enroll in the following classes. Engineering Management courses may not be used to fulfill the requirements of any other undergraduate or graduate degree offered by New Mexico Tech without prior approval by the chair of the other department.

EMGT 501, 501D, Management Science for Engineering Management,

3 cr, 3 cl hrs

This course will expose participants to up-to-date Management Science applications in engineering and technology organizations. Techniques include linear programming, inventory models, and material requirements planning.

EMGT 502, 502D, Financial Management, 3 cr, 3 cl hrs

This course begins with study of the interaction between financial and accounting systems and continues with a discussion of cash flow analysis. This foundation is followed by discussion of the latest in corporate financial management and capital budgeting techniques.

EMGT 503, 503D, Information Systems in Technology Organizations,

3 cr, 3cl hrs

Databases and the interaction between database information systems and organizational decision processes. Data mining and other topics relevant to data- and technology-intensive organizations. Discussion of the optimal information system design and implementation.

EMGT 504, 504D, Engineering Statistics 3 cr, 3 cl hrs

This course is designed to provide engineering managers with a basic foundation for data-driven decision making. Decisions by modern engineering managers increasingly require a range of statistical skills including gathering and describing data, designing samples and experiments, drawing statistical inferences and conclusions, evaluating the confidence of conclusions, developing regression models for anticipating future behavior and use of statistical quality control and six sigma to drive process improvement. All of these important capabilities must be utilized by a technical manager to make informed decisions.

EMGT 505, 505D, Marketing Technology, 3 cr, 3 cl hrs

Design, development, marketing, and sustaining of new products and technologies both inside and outside the engineering and technology organization. Market research, sampling and other data collection issues.

EMGT 506, 506D, Managing Technology Resources, 3 cr, 3 cl hrs

The study of human and other resources within technology and engineering organizations. Negotiation, leadership, resource allocation and other critical management topics will be discussed in this seminar. Research on organizational behavior issues unique to an engineering/technical environment will be studied.

EMGT 507, 507D, Organizational Entrepreneurship (Capstone), 3 cr, 3 cl hrs

Entrepreneurship is important for new startups and existing companies. This course is focused on development of skills that will assist in the advancement of innovations that will help innovators gain resources to support their efforts. Topics covered include game-theory based negotiation exercises, development of the value proposition for new products and services, and design of the business model in hyper-competitive environments.

EMGT 511, 511D, Financial Modeling, 3 cr, 3 cl hrs

Prerequisites: EMGT 502 and three other courses from EMGT 501-507 or consent of instructor

Portfolio optimization and other applications of Management Science techniques in a financial context. Analysis of domestic and international risky assets, including commodities, financial assets, and debt instruments. Coverage of the latest techniques in financial risk management, including hedging and other risk sharing techniques.

EMGT 512, 512D, Complex Financial Systems, 3 cr, 3 cl hrs

Prerequisite: EMGT 511 or consent of instructor

Modern financial systems are complex, interconnected, and sensitive to a variety of information from a variety of sources. This course is devoted to development and testing of valid simulation models of complex financial systems and the analysis of model outputs.

EMGT 521, Advanced Management Science Applications, 3 cr, 3 cl hrs

Prerequisites: EMGT 501 and three other courses from EMGT 501-507 or consent of instructor

Use of management science techniques such as Data Envelopment Analysis (DEA) to optimally solve resource allocation problems. Management Science techniques applied to public policy issues.

EMGT 522, 522D, Engineering Management Seminar, 3 cr, 3 cl hrs

Prerequisite: EMGT 507

Study of latest research data concerning engineering management issues. Issues such as measuring performance, project management, and human resource management in technology organizations where tasks and outcomes may be ill defined.

EMGT 571, 571D, 572, 572D, Topics in Engineering Management, 2–3 cr

Study of a special topic in Engineering Management not otherwise treated.

EMGT 581, 581D, Directed Study, cr to be arranged

Study a current topic in Engineering Management with a member of the faculty. Most directed study topics will be based on and grow out of Engineering Management program coursework.

EMGT 590, Final Project, cr to be arranged; at least 3 cr required

Corequisite: At least one elective-sequence course

Each program participant will be required to complete a project to complete the MS degree. This project, which will be supervised by at least two New Mexico Tech faculty members, is open-ended with regard to context and scope. Workplace applications are preferred, but any effort that is formally designed, carried out, and analyzed will be considered. Each project will be accompanied by a formal report that will be presented to a diverse audience in a formal setting.

MATH 585, Statistics for Technology Managers, 3 cr, 3 cl hrs

Probability and random variables; simple and multiple linear regression using least squares and other methods; experimental design; other topics including nonlinear regression; applications to decision making.

Faculty Research Interests

Anselmo—Decision Analysis and Risk Management, Computational Finance, Electronic Commerce

Mazumdar—Database Systems, Massive Storage Systems, Computational Logic

Ostergren—Program Management, Product Development, Total Quality Management

Peterson—Management, Economics, Accounting

Sueyoshi—Management Science, Data Envelopment Analysis, Risk and Policy Analysis

Environmental Engineering

*Professor Richardson (Chair of Department)
Associate Professors Carrico, Huang
Adjunct Faculty Brady, Hendrickx*

Degrees Offered: B.S. in Environmental Engineering; M.S. in Environmental Engineering

Department Mission Statement

The primary objective of this program is to produce well-balanced environmental engineers capable of entering the environmental engineering profession or continuing their studies at the graduate level. Graduates will be well-prepared to solve current environmental engineering problems, and they will have the ability to adapt to problems of the future.

By providing relevant experiences and building requisite technical skills and judgment cumulatively through rigorous problem solving, the program will instill the confidence needed for students to emerge as leaders in the field of environmental engineering.

Program Educational Objectives

1. To develop graduates that function successfully in areas of environmental engineering, such as air pollution, water and wastewater treatment, and solid and hazardous waste engineering.
2. To prepare graduates for advanced education in environmental engineering and related fields, and for professional licensure.

The achievements of environmental engineers are well-known to the general public, because environmental engineers are charged with producing clean water, disposing of waste responsibly, and maintaining air quality. Projects that environmental engineers work on include: design of water and wastewater treatment facilities, landfill design, design of air pollution control devices, and environmental law and permitting. The undergraduate program offers a balanced approach to environmental engineering education.

Students take a common core of engineering science and environmental engineering courses, including courses in environmental law, water and wastewater treatment, soil mechanics, soil and hazardous waste, hydrology and air pollution control. The environmental engineering courses teach students the fundamentals of engineering design, as well as potential applications. Students are taught how to use computer software to expedite the design process, and they are also taught how to balance engineering designs with economic constraints. During their senior year, undergraduate students work with a professor on a design thesis.

Undergraduate Program Bachelor of Science in Environmental Engineering

Minimum Hours Required—132

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- MATH 231 (4), 283 (3), 335 (3)
- BIOL 111 (3), 111L (1), 343 (3)
- EARTH 440 (4)
- ES 110 (2), 111 (3), 201 (3), 216 (3), 302 (3), 316 (3), 347 (3), 350 (3)
- ENVE 101 (1), 201 (3), 301 (3), 302 (2), 303 (3), 304 (3), 406 (3), 411 (4), 413 (4), 480 (3) or 490 (3)
- ME 420 (3)
- Technical Electives (3): Approved technical electives include ENVE 421, 491; CE 201, 301, 302, 401, 413, 420, 422, 423; EARTH 441, 442, 443; CHE 351, 352, 443; CHEM 333, 422; EE 211; ES 305, 332; MATE 430, 460, 470; ME 220, 409, 410, 422, 427; MENG 304, 305, 421; or other electives approved by the department chair.

Students pursuing a B.S. in Environmental Engineering must take all engineering courses for a letter grade. Environmental engineering majors must maintain a minimum GPA of 2.0 in required courses in order to graduate.

Environmental engineering majors are required to take the Fundamentals in Engineering (FE) exam as a requirement for graduation.

Sample Curriculum for the Bachelor of Science Degree in Environmental Engineering

Semester 1

- 1 ENVE 101 (environmental engineering seminar)
- 3 ENGL 111 (college English)
- 4 BIOL 111 & 111L (general)
- 4 CHEM 121 & 121L (general)
- 4 MATH 131 (calculus)
- 2 ES 110 (intro to engineering)
- 18 Total credits

Semester 2

- 3 ENGL 112 (college English)
- 3 ES 111 (computer programming for engineers)
- 4 MATH 132 (calculus)
- 4 CHEM 122 & 122L (general)
- 3 Social Science
- 17 Total credit hours

Semester 3

- 4 MATH 231 (calculus)
- 5 PHYS 121 & 121L (general)
- 3 ENVE 201 (intro to environmental engineering)
- 3 Humanities
- 15 Total credits

Semester 4

- 3 ENVE 301 (applied principles)
- 3 MATH 335 (ordinary differential equations)
- 3 PHYS 122 & 122L (general)
- 3 BIOL 343 (microbiology)
- 3 ES 201 (statics)
- 17 Total credits

Semester 5

- 3 ENVE 303 (water treatment process design)
- 3 ES 216 (fluid mechanics)
- 3 ES 302 (materials)
- 3 ES 347 (thermodynamics)
- 3 MATH 283 (statistics)
- 3 ME 420 (soil mechanics)
- 18 Total credits

Semester 6

- 2 ENVE 302 (environmental law)
- 3 ENVE 304 (wastewater treatment process design)
- 3 ES 316 (engineering economics)
- 3 ES 350 (heat & mass transfer)
- 3 ENGL 341 (technical writing)
- 3 Humanities
- 17 Total credits

Semester 7

- 4 ENVE 411 (solid and hazardous waste)
- 4 ENVE 413 (air pollution engineering)
- 4 EARTH 440 (hydrologic theory and field methods)
- 3 Social Science
- 15 Total credits

Semester 8

- 3 ENVE 406 (unit operations)
- 3 ENVE 480 or 490 (senior design or senior thesis)
- 3 Approved Technical Elective
- 3 Social Science
- 3 Humanities/Social Science
- 15 Total credits

Minor in Environmental Engineering

Minimum credit hours required – 18

The following courses are required:

- ENVE 201 (3), ENVE 301 (3)
- 12 additional hours of approved courses, including any ENVE courses, ME 420, or EARTH 440

Graduate Programs**Master of Science in Environmental Engineering**

The Environmental Engineering graduate program at New Mexico Tech provides a unique educational and research experience in the engineering and science of the natural environment and environmental protection. The plan of study and research is suited to each individual, drawing upon the strengths of the student, taking advantage of program capabilities, and complementing research activities within and outside New Mexico. A thesis or independent study project is required to complete the degree. General requirements common to all Master of Science degree curricula also apply.

Admission to the Master of Science in Environmental Engineering program requires competence in mathematics, chemistry, biology, physics, and engineering science comparable to the Bachelor of Science in Environmental Engineering. The department chair, or an advisory committee, will evaluate the scholastic record of every entering student to determine whether any deficiencies exist in their educational background. For example, students entering the program without an engineering degree may be required to take additional course work in such areas as fluid mechanics, heat and mass transfer, and differential equations before being granted a M.S. in Environmental Engineering. It is up to the student and his or her graduate committee to determine the specific plan of study for the student after the first semester of graduate work. Transfer credit for courses taken at another institution will be evaluated on an individual basis.

Thesis Option

A total of 30 credit hours are required for a M.S. in Environmental Engineering, which must include a minimum of 18 credit hours of Environmental Engineering coursework, and 6 credit hours of ENVE 591 (thesis). All students must take a minimum of 12 credit hours of 500-level Environmental Engineering courses.

Independent Study Option

A student may petition the department with the approval of the Department Chair to pursue a Master of Science degree with an independent study option. Candidates for the non-thesis Master of Science option must complete a minimum of 30 credit hours, of which 3 credit hours must be independent study (ENVE 590). All students must take a minimum of 12 credit hours of 500-level Environmental Engineering courses, and an additional 6 credits of 400- or 500-level Environmental Engineering courses (18 credits total). The student's course of study must be approved by the student's advisory committee, and it must fulfill the other requirements of the M.S. in Environmental Engineering degree program with the exception of 6 credit hours of thesis (ENVE 591).

Five Year Bachelor's/Master's Degree Program

A five-year B.S. /M.S. Environmental Engineering degree can be achieved by fulfilling the separate requirements of both the undergraduate degree and graduate degree. A combined minimum of 161 credit hours is required for the dual degree with at least 12 credit hours of 500-level ENVE courses and 6 credit hours of Thesis (ENVE 591). Students in the five-year program are also required to take ENVE 581 (summer). A B.S. degree in Environmental Engineering will be granted after the five-year student has completed the 135 credit-hour undergraduate requirement. For the M.S. degree, the 6 credit hours of required graduate electives must be non-ENVE courses of 300-level and above. Students with a minimum GPA of 3.0 are eligible to apply for the admission to the graduate program after the first semester of their junior year. Once admitted to the graduate program, the five-year student will spend his/her senior year as a dual registered student and all rules for graduate student status apply. A sample curriculum for the five-year B.S. / M.S. Environmental Engineering degree is listed below.

Summer

3 ENVE 581

Semester 7

4 ENVE 411

4 ENVE 413

4 EARTH 440

3 Social Science

15 Total credit hours

Semester 8*

3 ENVE 406

3 ENVE 490

3 ENVE 510

3 Humanities/Social Science

12 Total credit hours

*B.S. degree is granted

Summer

3 ENVE 591

Semester 9

3 ENVE 501

3 ENVE 503

3 ENVE 512

3 ENVE 591

12 Total credit hours

Semester 10

3 ENVE 520

3 Elective

3 Elective

3 ENVE 591 (optional)

12 Total credit hours

Summer

3 ENVE 591 (optional)

Environmental Engineering Courses:

ENVE 101, Environmental Engineering Seminar, 1 cr, 1 cl hr

Seminars by faculty, and guest speakers from industry, consulting, and government provide a brief overview of environmental engineering topics, including air pollution, water quality, and solid and hazardous waste.

ENVE 201, Introduction to Environmental Science and Engineering, 3 cr, 3 cl hr

Prerequisites: CHEM 122 & 122L; BIOL 111 & 111L; MATH 132

The fundamentals of physics, chemistry, biology, and geology applied to problem solving in science and engineering. A study of environmental phenomena and strategies to control pollution of water, air, and land. Definition of basics for water quality engineering, water treatment, wastewater treatment, solid and hazardous waste management, radioactive waste management, and air pollution. Environmental impact statements and environmental ethics.

ENVE 301, Applied Principles of Environmental Engineering, 3 cr, 3 cl hrs

Prerequisites: ENVE 201

Application of chemical and biological principles to the study of the natural environment and engineered systems related to pollution of air, water, and soil. Topics include: atmospheric chemistry, biokinetics, carbonate cycle, corrosion, complexation (coordination chemistry), redox reactions, and precipitation. Principles will be tied to specific environmental engineering applications.

ENVE 302, Environmental Law and Regulations, 2 cr, 2 cl hrs

Prerequisite: ENVE 201

An overview of the major federal and state environmental statutes and regulations. Statutory/regulatory scheme and its application to current environmental problems. Specific regulations pertaining to air, water, toxic substances and pesticides, and solid and hazardous wastes, as well as related regulatory programs. Historical and philosophical basis of environmental regulation.

ENVE 303, Water Treatment Process Design, 3 cr, 3 cl hrs

Prerequisites: ENVE 201 or consent of instructor

Physical-chemical processes encountered in the design, analysis, and operation of municipal and industrial water treatment systems. Concepts of mass balance and chemical reactor theory applied to water quality improvements. Specific topics include flocculation/coagulation, softening, sedimentation, filtration, stabilization, disinfection, ion exchange, carbon adsorption, and gas transfer. A team design project will be required as partial fulfillment of course requirements.

ENVE 304, Wastewater Treatment Process Design, 3 cr, 3 cl hrs

Prerequisites: BIOL 343; ES 216, 350; or consent of instructor

Physical-chemical-biological processes encountered in the design, analysis, and operation of municipal and industrial wastewater treatment systems. Microbial kinetics of carbon and nutrient removal. Aerobic and anaerobic biological processes occurring in suspended growth and fixed-film reactors. Processing, management, and disposal of biosolid residuals. Specific topics include collection, pretreatment, sedimentation, trickling filters, activated sludge aerobic and anaerobic digestion. A team design project will be required as partial fulfillment of course requirements.

ENVE 406, Environmental Engineering Unit Operations, 3 cr, 2 cl, 3 lab hrs

Corerequisites: ENVE 303 or 304 or consent of instructor

Laboratory and field studies of unit operations and processes in environmental engineering. A student-designed feature will be integrated into all of the studies. Potential topics include reactor mixing and hydraulics, coagulation, flocculation, sedimentation, filtration, carbon adsorption, chemical oxidation, air stripping, etc. Emphasis on planning of studies, preparation of work plans, data collection and analysis, report writing, and technical presentation.

ENVE 411, Solid and Hazardous Waste Engineering, 4 cr, 4 cl hrs

Prerequisites: ES 350 or consent of instructor

A study of solid waste management functions: generation, transport, storage, treatment and recovery, and disposal. Emphasis on design of treatment and recovery unit operations and processes for both municipal and industrial wastes. Site selection criteria and engineering considerations for land disposal alternatives. Special consideration of hazardous waste management: treatment, storage, disposal. Uncontrolled hazardous waste sites: risk assessment and remediation design. Projects on waste management will be developed by teams as partial fulfillment of course requirements.

ENVE 413, Fundamentals of Air Pollution Engineering, 4 cr, 3 cl, 3 lab hrs

Prerequisites: ES 216 and 350; or consent of instructor

Sources, behavior, and fate of gaseous and particulate air pollutants. Principles of meteorology and atmospheric diffusion in relation to modeling pollutant transport and dispersion. Design of air pollution control equipment for removal of gases and particles from air streams. Unit operations examined include cyclones, electrostatic precipitators, fabric filters, wet scrubbers, incinerators, biofiltration, adsorbers, and absorbers. In the laboratory section, students will develop an air permit, and complete projects using dispersion modeling and air pollution engineering software. Shares lecture with ENVE 513, with additional expectations for graduation credit.

ENVE 421, Green Engineering, 3 cr, 3 cl hrs

Prerequisite: junior standing

Evaluating the full range of environmental effects associated with products and services from raw materials acquisition and manufacturing to use and disposal. Industrial processes, potential waste minimization procedures, relevant regulations as well as life-cycle analysis. Shares lecture with ENVE 521, with additional expectations for graduate credit.

ENVE 480, Environmental Engineering Senior Design, 3 cr

Prerequisite: Senior standing and consent of instructor

Design of equipment, unit processes, and systems in environmental engineering through application of scientific, technological, and economic principles. Emphasis is placed upon problem formulation and the conceptual, analytical, and decision aspects of open-ended design situations. Course integrates knowledge and skills gained in previous and concurrent courses. Students work as a team in a local, regional or national design competition. A team project report is required. Instructors may also require interim reports, an individual final report, and a final presentation.

ENVE 490, Senior Design Thesis, 3 cr

Prerequisite: Senior standing or consent of instructor

Design of equipment, unit processes, and systems in environmental engineering through application of scientific, technological, and economic principles. Emphasis is placed upon problem formulation and the conceptual, analytical, and decision aspects of open-ended design situations. Course integrates knowledge and skills gained in previous and concurrent courses.

ENVE 491, Special Topics in Environmental Engineering, 3 cr, 3 cl hrs

Prerequisite: Senior standing or consent of instructor

ENVE 501, Physicochemical and Biological Processes, 3 cr, 3 cl hrs

Fundamentals of physical, chemical, and microbial processes in natural and engineered remedial systems. Phase interactions, chemical transformations, transport phenomena, and separation processes in the natural and engineered systems. Characteristics of microorganisms, microbial ecology, biokinetics, and nutrient requirements. The role of microorganisms in treatment processes and the monitoring and enhancement of *in-situ* activity.

ENVE 503, Environmental Risk Assessment, 3 cr, 3 cl hrs

Multi-disciplinary approaches required to develop credible risk analysis within the U.S. regulatory and social framework. Philosophical contexts, regulatory framework, and economic implications. Components of risk and performance assessments, including source term, contaminant transport, exposure, and consequences. Computer models and case studies.

ENVE 510, Advanced Water Chemistry, 3 cr, 3 cl hrs

Advanced study of physical and organic chemistry as applicable to natural water bodies and water and wastewater treatment. Chemical cycles, equilibrium chemistry, chemical thermodynamics, reaction kinetics, precipitation and dissolution, oxidation and reduction, colloidal and surface chemistry, complexation phenomena, electroneutrality, mass balances, and transport and fate of chemical species. Relevance of these topics to water quality control are discussed.

ENVE 511, Water Quality Management and Control, 3 cr, 3 cl hrs

Prerequisite: MATH 335 or consent of instructor

Fundamentals of water quality, including water bodies and their natural setting, water uses and waste input, and water quality cause-effect relationships. Water quality parameters, criteria, and standards; principles of water quality systems analysis, both in the formulation and application of water quality models; engineering controls and socio-economic concepts of water quality management and control, including cost/benefit analysis and management modeling.

ENVE 512, Industrial Water and Wastewater Treatment, 3 cr, 3 cl hrs

Prerequisites: ENVE 303, 304, 501; or consent of instructor

Advanced study of treatment unit operations and processes within industry-specific water and wastewater situations. Process design, specifications, and costing of physical, chemical, or biological technology to meet a particular treatment objective. Subject matter is developed through references to current practice, critique of completed designs, design exercises, and field trips.

ENVE 513, Air Resources Engineering, 4 cr, 3 cl, 3 lab hrs

Prerequisites: ES 216 and 350; or consent of instructor

Sources, behavior, and fate of gaseous and particulate air pollutants. Principles of meteorology and atmospheric diffusion in relation to modeling pollutant transport and dispersion. Design of air pollution control equipment for removal of gases and particles from air streams. Unit operations examined include cyclones, electrostatic precipitators, fabric filters, wet scrubbers, incinerators, biofiltration, adsorbers, and absorbers. In the laboratory section, students will develop an air permit, and complete projects using dispersion modeling and air pollution engineering software. Graduate students complete an additional project and a classroom presentation. Shares lecture with ENVE 413, with additional expectations for graduate credit.

ENVE 520, Hazardous Waste Site Remediation, 3 cr, 3 cl hrs

Prerequisites: ENVE 411, 501; or consent of instructor

Design and specification of various physical, chemical, thermal, and biological technologies commonly used in the cleanup of hazardous waste sites. Special emphasis on innovative and emerging technologies for site remediation. Proper sampling and monitoring procedures. Emergency technology in hazardous waste management.

ENVE 521, Green Engineering, 3 cr, 3 cl hrs

Evaluating the full range of environmental effects associated with products and services from raw materials acquisition and manufacturing to use and disposal. Industrial processes, potential waste minimization procedures, relevant regulations as well as life-cycle analysis. Shares lecture with ENVE 421, with additional expectations for graduate credit.

ENVE 522, Geotechnical Waste Containment Design, 3 cr, 3 cl hrs

Prerequisite: ME 420 or consent of instructor

Design procedures consisting of waste disposal methods, various containment systems, and associated remediation techniques. Waste characterization and soil-waste interactions, contaminant transport in low permeability soils, geosynthetics and soil materials use in waste containment, remedial issues of solidification and stabilization and barrier design, and landfill- and surface impoundment-related design, including liners, leachate and gas collection and removal, final covers, static and seismic slope stability, and settlement analysis. Geotechnical problem definition, application of field and laboratory test data, use of computer models for analysis and design.

ENVE 523, Open Channel Hydraulics, 3 cr, 3 cl hrs

Prerequisite: ES 216 or consent of instructor

Analysis and characteristics of flow in natural and artificial open channel systems using energy, continuity, and momentum equations as applied to steady-state uniform, gradually varied, and rapidly varied flow profiles with emphasis on design of hydraulic structures. The students will use their knowledge of fluid mechanics, calculus, numerical analysis, and computer science to solve practical open channel flow problems. A variety of hydraulic conveyance and structures are covered, including rigid and flexible boundary channels, culverts, sluice gates, fumes, weirs, spillways, stilling basins, and bridges. Shares lecture with CE 423, with additional expectations for graduate credit.

ENVE 551, Graduate Seminar, 1 cr each semester

Seminar presentations by faculty, graduate students, and guest speakers on their interests and current research topics. Graded on S/U basis.

ENVE 571, Special Topics in Environmental Engineering, 2–4 cr, 2–4 cl hrs

Prerequisite: Consent of instructor

Offered on sufficient demand

Special topics in environmental engineering.

ENVE 581, Directed Study, credit to be arranged

Independent design project conducted by the student under the direction of the student's advisor. A written final report and oral presentation are required.

ENVE 590, Independent Study, cr to be arranged

Independent research organized and conducted by the student under the direction of the student's advisor. A written final report is required

ENVE 591, Thesis (Master's Program), credit to be arranged**Faculty Research Interests**

- Brady—Aquatic chemistry, global change, groundwater remediation
- Carrico—Air quality engineering, aerosols, global change, energy and environmental impacts
- Hendrickx—Vadose zone hydrology, water and salt balance of natural and irrigated systems, evapotranspiration, remote sensing, soil physics, electromagnetic induction
- Huang—Hazardous waste management, water treatment, wastewater reuse
- Richardson—Biological wastewater treatment, environmental risk assessment, groundwater contamination, site remediation

Materials and Metallurgical Engineering

Professors: Burleigh, Fuierer, Majumdar, McCoy

Associate Professor: Henneke, Kalugin (Chair of the Department)

Joint Appointment Professors: Leclerc (ChE), Tartis (ChE), Teare (EE)

Adjunct Faculty: Chambers, Curro, Hargather, Hirschfeld, Jacobson, Kropka, Prasad, Romig, M. Smith, Vianco, Vogel

Emeritus Professor: Bond

Degrees Offered: B.S. in Materials Engineering, Materials Engineering with Metallurgical Engineering Option, Materials Engineering with Biomaterials Engineering Option; M.S. and Ph.D. in Materials Engineering

Web site: <http://infohost.nmt.edu/~mtls/>

Department Mission Statement

- To educate our students so that they are prepared to obtain and succeed in the best positions in industry, government laboratories, and graduate schools.
- To advance the frontiers of materials science and engineering.
- To serve the public of New Mexico through outreach and expanded education.

Program Educational Objective

Program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. The Materials Engineering program will prepare graduates who:

1. Establish themselves in a range of careers in industry or government or pursue post baccalaureate education in engineering, science, business, law, medicine, or related fields;
2. Advance in their chosen profession; and
3. Engage in appropriate professional societies and in continuing education activities

Undergraduate Program (ABET Accredited)

Advanced technologies often initiate with innovations in new materials, such as in the electronic or aerospace industries. These material innovations rest on a fundamental understanding of how the internal structure of a material influences properties at different length scales, ranging from sub-atomic, to nano, to micro, and ultimately macro-scale. The state of the material at these length scales are probed by various characterizing methods, which provide understanding of mechanisms responsible for observed phenomenon. Thereby material problems can be resolved and innovations made that are both efficient and based on solid scientific principles. The undergraduate materials program attempts to provide these foundations in an academic atmosphere that fosters growth and collaboration. With a small class size, students have the opportunity to interact closely with professors and conduct research in laboratories.

Students are exposed to materials science principles starting from their sophomore year and which continue through their senior year. A number of options are available in the department so that students have the flexibility to select courses that suit a specialization. In particular, a Biomaterials Option has just recently been instituted in light of engineering needs in the rapidly growing biotechnology industry. In addition to theoretical courses, students obtain an excellent experience in processing and characterization techniques during their junior and senior years, these constituting the core of most experimental research and innovations. Material probing methods include spectroscopic (e.g. X-ray, FTIR, Raman), electron microscopic, thermal, and mechanical characterization.

The processing-structure-property relations are developed and expanded upon throughout the undergraduate curriculum. Four classes in the junior year target the theories used to understand characteristics of metals, ceramics, polymers, and composites. Senior-level elective materials courses target specialized topics such as electronic, structural, nanomaterials, biomaterials, and computational materials science. The senior design sequence emphasizes the synthesis of skills and ideas as well as providing experience in teamwork and practical design.

Research experience for the students is available and encouraged through part-time employment in the broad range of Materials research projects that are on-going in the department and also in other in-house research entities, such as the Energetic Materials Research and Testing Center and the Petroleum Recovery Research Center. Departmental collaborations with scientists at Los Alamos and Sandia National Laboratories provide another avenue for student involvement in research projects. Many of our students pursue graduate degrees either at New Mexico Tech or elsewhere while others seek employment directly.

The department operates and maintains a broad range of instrumentation. A full list of these resources is available on the department's web site. Of particular note is the broad range of microscopy capabilities for research and instruction, including scanning electron microscopes, Auger probe and a scanning probe (atomic force) microscope.

Bachelor of Science in Materials Engineering

Minimum credit hours required—131

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- MATH 231 (4), 335 (3)
- ES 110 (2), 111 (3), 201 (3), 302 (3), 332 (3) or EE 211 (3)
- MATE 101L (1), 202 & 202L (4), 235 & 235L (4), 301 (3), 310 (3), 311 (3), 314 (3), 350 (3), 351 (3), 410 (3), 445 (3), 481 (3), 482 (3)
- METE 327 (3)
- Advanced basic science (3): CHEM 311, 331, 333 or MATE 452 are recommended; advisor approval is required.
- Technical electives (12): Approved upper level MATE and METE courses. Up to 3 credit hours can be completed outside the department with the consent of the department.
- Electives to complete 131 credit hours

Credit for trigonometry or college algebra is not allowed for engineering students.

Sample Curriculum for the Bachelor of Science in Materials Engineering

Semester 1

- 1 MATE 101L (Intro. Materials Lab)
- 3 ENGL 111 (College English 1)
- 4 MATH 131 (Calculus 1)
- 4 CHEM 121 & 121L (General Chemistry 1)
- 3 Social Science
- 2 ES 110 (Intro. to Engineering)
- 17 Total credit hours

Semester 2

- 3 ENGL 112 (College English 2)
- 4 MATH 132 (Calculus 2)
- 4 CHEM 122 & 122L (General Chemistry 2)
- 3 ES 111 (Computer Programming)
- 3 Humanities
- 17 Total credit hours

Semester 3

- 4 MATE 202 & 202L (General Materials 1)
- 4 MATH 231 (Calculus 3)
- 5 PHYS 121 & 121L (General Physics 1)
- 3 Humanities
- 16 Total credit hours

Semester 4

- 3 MATH 335 (Applied Analysis)
- 5 PHYS 122 & 122L (General Physics 2)
- 4 MATE 235 & 235L (General Materials 2)
- 3 ES 201 (Statics)
- 3 Social Science
- 18 Total credit hours

Semester 5

- 3 Humanities/Social Science
- 3 ES 302 (Mechanics of Materials)
- 3 MATE 301 (Ceramics)
- 3 MATE 350 (Materials Thermodynamics)
- 3 MATE 310 (Processing and Microstructure)
- 15 Total credit hours

Semester 6

- 3 ENGL 341 (Technical Writing)
- 3 ES 332 or EE 211 (Electrical Engineering)
- 3 METE 327 (Physical Metallurgy)
- 3 MATE 351 (Polymers)
- 3 MATE 314 (Transport Processes)
- 3 MATE 311 (Thermal and Mechanical Properties)
- 18 Total credit hours

Semester 7

- 3 Technical Elective*
- 3 Technical Elective*
- 3 MATE 445 (Composites)
- 3 MATE 481 (Senior Design 1)
- 3 MATE 410 (Microstructural Characterization)
- 15 Total credit hours

Semester 8

- 3 Technical Elective*
- 3 Technical Elective*
- 3 Advanced Basic Science Elective*
- 3 MATE 482 (Senior Design 2)
- 3 Humanities/Social Science
- 15 Total credit hours

* Electives must be approved by the student's advisor.

Bachelor of Science Degree in Materials Engineering with Metallurgical Engineering Option

Minimum credit hours required—131

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- MATH 231 (4), 335 (3)
 - ES 110 (2), 111 (3), 201 (3), 302 (3), 332 (3) or EE 211 (3)
 - MATE 101L (1), 202 & 202L (4), 235 & 235L (4), 310 (3), 311 (3), 314 (3), 350 (3), 410 (3), 435 (3), 481 (3), 482 (3)
 - METE 327 (3)
 - Two of the following: MATE 301 (3), MATE 351 (3), MATE 445(3)
 - Advanced basic science (3): MATE 452 is recommended.
 - Technical electives (12): Approved upper level MATE and METE courses. Up to 3 credit hours can be completed outside the department.
 - Electives to complete 131 credit hours
- Credit for trigonometry or college algebra is not allowed for engineering students.

All engineering majors are required to take the Fundamentals in Engineering (FE) exam as a requirement for graduation.

Sample Curriculum for the Bachelor of Science in Materials Engineering with Metallurgical Engineering Option

Semester 1

1 MATE 101L (Intro. Materials Lab)
 3 ENGL 111 (College English 1)
 4 MATH 131 (Calculus 1)
 4 CHEM 121 & 121L (Chemistry 1)
 3 Social Science
2 ES 110 (Intro. to Engineering)
 17 Total credit hours

Semester 2

3 ENGL 112 (College English 2)
 4 MATH 132 (Calculus 2)
 4 CHEM 122 & 122L (Chemistry 2)
 3 ES 111 (Computer Programming)
3 Humanities
 17 Total credit hours

Semester 3

4 MATE 202 & 202L (Materials 1)
 4 MATH 231 (Calculus 3)
 5 PHYS 121 & 121L (Physics 1)
3 Humanities
 16 Total credit hours

Semester 4

3 MATH 335 (Applied Analysis)
 5 PHYS 122 & 122L (Physics 2)
 4 MATE 235 & 235L (Materials 2)
 3 ES 201 (Statics)
3 Social Science
 18 Total credit hours

Semester 5

3 Humanities/Social Science
 3 ES 302 (Mechanics of Materials)
 3 MATE 350 (Materials Thermodynamics)
 3 MATE 310 (Processing and Microstructure)
3 MATE 301 or MATE 445 **
 15 Total credit hours

Semester 6

3 MATE 311 (Thermal and Mechanical Properties)
 3 MATE 314 (Transport Processes)
 3 MATE 351 (Polymers)**
 3 METE 327 (Physical Metallurgy)
 3 ES 332 or EE 211 (Electrical Engineering)
3 ENGL 341 (Technical Writing)
 18 Total credit hours

Semester 7

3 Technical Elective*
 3 Technical Elective*
 3 MATE 481 (Senior Design 1)
 3 MATE 410 (Microstructural Characterization)
3 Humanities/Social Science
 15 Total credit hours

Semester 8

3 Technical Elective*
 3 Technical Elective*
 3 Advanced Basic Science Elective*
 3 MATE 482 (Senior Design 2)
3 MATE 435 (Mechanical Behavior)
 15 Total credit hours

* Electives must be approved by the student's advisor.

** Two of the following: MATE 301 (Ceramics) (3), MATE 351 (Polymers) (3), or MATE 445 (Composites)(3).

Bachelor of Science Degree in Materials Engineering with Biomaterials Engineering Option

Minimum credit hours required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- MATH 231 (4), 335 (3)
- ES 110 (2), 111 (3), 201 (3), 302 (3), 332 (3) or EE 211 (3)
- MATE 101L (1), 202 & 202L (4), 235 & 235L (4), 301 (3), 314 (3), 350 (3), 351 (3), 481 (3), 482 (3)
- METE 327 (3)
- Two of the following: MATE 310 (3), 311 (3), 410(3)
- BIOL 111, 111L (4), BIOL 331 (3), BIOL 333, 333L (4), MATE 4xx/5yy (3)
- Technical electives (6): Suggested electives include BIOL 341 (3), 351 (3); ChE 473 (3); CHEM 333, 333L (4), 334, 334L (4); MATE 445 (3), 470 (3); MATH 283 (3), 382 (3); MENG 460 (3), 465 (3), 489 (3), 576 (3). Alternative or additional technical electives must be approved by the Department Chair.

Sample Curriculum for the Bachelor of Science in Materials Engineering with Biomaterials Engineering Option

Semester 1

1 MATE 101L (Intro. Materials Lab)
 3 ENGL 111 (College English 1)
 4 MATH 131 (Calculus 1)
 4 CHEM 121 & 121L (Chemistry 1)
 3 Social Science
2 ES 110 (Intro. to Engineering)
 17 Total credit hours

Semester 2

3 ENGL 112 (College English 2)
 4 MATH 132 (Calculus 2)
 4 CHEM 122 & 122L (Chemistry 2)
 3 ES 111 (Computer Programming)
3 Social Science
 17 Total credit hours

Semester 3

4 MATE 202 & 202L (Materials 1)
 4 MATH 231 (Calculus 3)
 5 PHYS 121 & 121L (Physics 1)
4 BIOL 111 & 111L (Biology 1)
 17 Total credit hours

Semester 4

3 MATH 335 (Applied Analysis)
 5 PHYS 122 & 122L (Physics 2)
 4 MATE 235 & 235L (Materials 2)
 3 ES 201 (Statics)
3 Humanities
 18 Total credit hours

Semester 5

3 METE 327 (Metals)
 3 BIOL 331 (Cell Biology)
 3 ES 302 (Mechanics of Materials)
 3 MATE 350 (Materials Thermodynamics)
3 MATE 4xx/5yy (Biomaterials)
 15 Total credit hours

Semester 6

3 MATE 311 (Thermal and Mechanical Properties)
 3 MATE 314 (Transport Processes)
 3 METE 326 (Process Metallurgy)
 3 METE 327 (Physical Metallurgy)
 3 ES 332 or EE 211 (Electrical Engineering)
 3 ENGL 341 (Technical Writing)
3 Humanities
 18 Total credit hours

Semester 7

3 Technical Elective*
 3 Social Science/Humanities
 3 Social Science/Humanities
 3 MATE 481 (Senior Design 1)
3 MATE 410 (Microstructural Characterization)
 15 Total credit hours

Semester 8

4 BIOL 333, 333L (Molecular Biology)
 3 Technical Elective*
 3 MATE 482 (Senior Design 2)
3 Social Science/Humanities
 13 Total credit hours

* Electives must be approved by the student's advisor.

Minor in Materials Engineering

Minimum credit hours required—17

The following courses are required:

- MATE 202 and MATE 235 (6+).
- Approved Technical Electives (to yield total of 17).

Minor in Polymer Science

Minimum credit hours required—19

The following courses are required:

- CHEM 334 (3), 446 (3)
- MATE 202 & 202L (4) or 235 & 235L (4)
- MATE 351 (3)
- Approved Technical Electives (6)

Graduate Programs**Master of Science in Materials Engineering Thesis Option**

The Thesis Option prepares students for high quality research (and is often preferred for admission into PhD programs around the country). Full time graduate students must formalize an advisory committee that will consist of an academic advisor from the department and at least two additional members. The selection of an advisor must be completed by the end of the first semester while the remaining members of the committee along with thesis topic must be decided by the end of the second semester. Department faculty must not be in the minority in the committee. Part time or DE students must formalize their advisor by the time they complete 12 credits. The student must meet with his or her committee at least once per year.

The Course Requirements include:

(A) At least 24 credit hours of course work that must include: (i) a minimum of 12 credit hours of 500 level courses, and (ii) at least 6 hours of upper level (300+) courses outside the Materials Department, unless the student is from a non-Materials background. No more than 3 hours of MATE 581 Directed Study.

(B) 6 credit hours of MATE 591 (Thesis) that will be defended in a public oral defense. Students may take MATE 500 (Directed Research) in multiple semesters but the credits may not count toward their degree requirements.

Graduate students must take MATE 592 each semester offered. The student may appeal to their advisory committee for possible exception.

Courses must be approved by the advisory committee, and the research should be directed toward a journal publication. Students must inform faculty advisors in advance regarding courses that they plan to take in the following semester.

Students are required to write a thesis proposal (or independent study proposal) and defend it in a public oral defense before the advisory committee at least one full semester (fall or spring) before the final defense.

The final thesis must be successfully defended in a public oral defense before the advisory committee.

Additional requirements for the MS degree include the New Mexico Tech General Graduate Program Requirements.

Master of Science in Materials Engineering, Independent Study Option

A student may petition the department with the approval of the faculty to pursue a Master of Science degree with an Independent Study Option. The selection of committee members and the research topic must follow the same requirements as those for the Master's Thesis Option.

The Course Requirements include:

(A) At least 27 credit hours of course work that must include: (i) a minimum of 15 credit hours of 500 level courses and (ii) at least 6 hours of upper level (300+) courses outside the Materials Department, unless the student is from a non-materials background.

(B) 3 credit hours of MATE 590 (Independent Study) that will be defended in a public oral defense. Students may take MATE 500 (Directed Research) in multiple semesters but the credits will not count towards their degree requirements.

Courses must be approved by the advisory committee. Students must inform faculty advisors in advance regarding courses that they plan to take in the following semester. The MATE 592 requirements as stated in the Master's Thesis Option will also be applicable here.

Students are required to write an independent study proposal and defend it in a public oral defense before the advisory committee at least one full semester (fall or spring) before the final defense. The final Independent Study must be successfully defended in a public oral defense before the advisory committee.

Additional requirements for the MS degree include the New Mexico Tech General Graduate Program Requirements.

Combined Five Year Bachelor of Science/Master of Science Degree Program

The combined degrees of a MS in Materials Engineering (either Thesis or Independent Study Option) along with a BS in Materials Engineering or affiliated field may be achieved in five years. For students in MATE or METE BS programs, a minimum of 158 credit hours are required to complete the combined (BS+MS) degree. For students in affiliated BS programs, there are commensurate requirements. Students must fulfill all the requirements for their BS program and, depending upon their selection of a Thesis or Independent Study Option, complete the following additional requirements:

- **Thesis Option:** (i) A minimum of 12 credit hours of 500 level courses; (ii) 9 additional credit hours of upper or 500 level courses that may include no more than 3 credit hours of MATE 491 (directed study), (iii) 2 credit hours of MATE 592, and (iv) 6 credit hours of MATE 591 (Thesis) that will be defended in a public oral defense.
- **Independent Study Option:** (i) A minimum of 15 credit hours of 500 level courses, (ii) 9 additional hours of upper or 500 level courses that may include no more than 3 credit hours of MATE 491 (Directed Study), (iii) 2 credit hours of MATE 592, and (iv) 3 credit hours of MATE 590 (Independent Study) that will be defended in a public oral defense.

Students graduating with a BS in Materials Engineering must include a minimum of 6 credit hours of approved upper-division or graduate course work from other departments in the above list, as part of the general breadth requirements for the MS degree. The breadth requirement may be waived for non-materials students, but they are highly encouraged to take all courses towards their MS degree in Materials Engineering. The student must select courses in close consultation with the MS advising committee and research work should be directed towards a publication. Students for the 5-year program must apply for graduate standing, normally in their 6th semester. Admission is contingent upon their having a 3.0 GPA and the acceptance of their proposed course of study. Students with upper division standing may apply, but admittance into the program will be conditional. Graduate admission will be contingent upon adherence to the approved programs of study and a 3.0 minimum overall cumulative GPA. Graduate status will be granted upon fulfillment of the requirements for the BS degree.

Doctor of Philosophy in Materials Engineering

The prospective doctoral candidate should develop a good background in materials sciences, chemistry, physics, and mathematics, in addition to achieving a high level of competence in a specialized area of materials. Programs are arranged by the prospective student and the student's advisory committee.

The PhD requirements include the following:

1. Select an advisory committee that shall consist of a minimum of four members: (a) an academic advisor from the Materials department, (b) at least three other members out of which one must be from outside the department (not necessarily from a different field). The research advisor may be the academic advisor or other member of the committee. Materials faculty shall not be in the minority on the advisory committee. The student must select an academic advisor, who may serve as a temporary research advisor, before the second semester of study. The selection of the entire committee and dissertation topic must be completed by the end of the second semester of study for full-time in-house students, and immediately after completing 12 credit hours for DE students. The student must meet with his or her committee at least once per year, and must get courses approved by them.
2. Complete at least 24 credit hours of courses approved by the doctoral committee, including:
 - (i) at least 12 hours of 500 level courses. No more than 3 hours of MATE 581 Directed Study may be used for fulfilling the course requirements. Students may take MATE 500 (Directed Research) in multiple semesters but the credits may not count towards their degree requirements. Graduate students must take MATE 592 each semester offered. The student may appeal to their advisory committee for possible exception.
 - For students who have already received an MS degree from the Materials department, the total credit requirements for course work may be reduced below 24 credits with the approval of their committee, department chair, and the graduate dean.
3. Conduct a successful written and public oral critique of a paper published in a high quality professional journal. The paper choice shall be agreed on by the doctoral committee. The paper critique is the Materials Department's **Preliminary** (alternately called qualifying) examination. This is the first examination that a student has to pass. During the paper critique presentation, the student may be asked questions relating to background knowledge gained from taking regular coursework in materials and related subjects. The paper critique must be completed within 18 months of enrolling into the PhD program.
4. Write a research proposal and defend it in a public oral defense at least two full semesters before the final dissertation defense. This proposal defense is the Materials Department **Candidacy** exam, and should address the rationale for the research plan and preliminary work in progress. This examination can only be taken after a student has passed the preliminary examination.
5. The admission to candidacy to the PhD degree requires that the preliminary and candidacy examinations be passed and approved by the advisory committee. Following this, the student must enroll in at least 24 credit hours of MATE 595 Dissertation during which the student completes the research project approved by the advisory committee. The student cannot start taking MATE 595 credits until both the preliminary exam (paper critique) and the candidacy exam (proposal defense) have been passed.
6. A full-time graduate student must be enrolled in a minimum of 9 credit hours per regular semester and 6 credit hours during the summer.
7. The student must submit at least one paper based on the dissertation to a recognized journal acceptable to the doctoral committee. A preprint must be submitted to the doctoral committee prior to defense of the PhD dissertation. It is preferable that this paper be accepted by the journal and a written copy of the acceptance or conditional acceptance with reviewer comments should be provided to the committee.
8. The student must write the final dissertation and defend it in an oral public defense before the doctoral committee.

Additional requirements include the New Mexico Tech General Graduate Program Requirements.

Materials Engineering Courses:

MATE 101L, Introductory Materials Engineering Laboratory, 1 cr, 3 lab hrs

Hands-on laboratory experience with some fundamental concepts in materials engineering: classification of solids, gelation processes, particulate dispersions, nucleation and growth of crystals, phase diagrams, magnetic domains, (explosive) welding, and composite design. Course provides a glossary of terms and concepts used in the field of materials science and engineering.

MATE 202, Materials Engineering I, 3 cr, 3 cl hrs

Corequisite: CHEM 122

Application of the student's background in physical sciences, mathematics, and computer science to the solution of elementary problems in the materials sciences. Introduction to metallurgical techniques and the science of materials. Elementary design problems involving the optimum use of materials.

MATE 202L Materials Engineering I Laboratory, 1 cr, 3 lab hrs

Corequisite: MATE 202

Laboratory experiments addressing elementary design problems involving optimal use of materials. Designed to reinforce principles discussed in Mate 202.

MATE 235 Materials Engineering II, 3 cr, 3 cl hrs

Prerequisites: CHEM 122 and 122L

Corequisite: Phys 122 & 122L

Survey of technologically important materials including ceramics, glasses, semiconductors, polymers and composites. The objective is to understand the chemical composition, structure, processing and property relationships in material systems. The student will obtain a basic understanding of the principles of electronic transport, dielectric, thermal, optical and mechanical properties of engineered solids. Undergraduate students majoring in Materials Engineering must take Mate 235L concurrently.

MATE 235L Materials Engineering II Laboratory, 1 cr, 3 lab hrs

Prerequisites: CHEM 122 and 122L

Corequisites: MATE 235

Laboratory experiments introducing the fabrication of technical materials and the measurement of their properties. Designed to reinforce principles discussed in Mate 235.

MATE 301, Introduction to Ceramic Engineering, 3 cr, 3 cl hrs

Prerequisites: MATE 235; or consent of instructor

Ceramic processing from raw materials to finished products. Chemistry and structure of ceramic raw materials. Ceramic powder preparation and characterization. Engineering ceramic suspensions. Microstructures of traditional (porcelain and glass) and advanced (modern structural and electrical) ceramics. Properties of ceramics, and their dependence on processing and microstructure.

MATE 310 Processing and Microstructure Methods and Analysis 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: MATE 202, MATE 235; or consent of instructor

Emphasis on the relationship between processing and microstructure. Processing techniques used to form metals, ceramics, polymers, and composites will be studied such as extrusion, pressing, forging, rolling, casting, and joining. Elementary analysis techniques such as optical and electron microscopy will be used to illustrate the effect of processing on microstructure.

MATE 311 Thermal and Mechanical Methods and Analysis 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: MATE 202, MATE 235, ES 302; or consent of instructor

Emphasis on the use of thermal and mechanical techniques to both influence and measure the properties of metals, polymers, ceramics, and composites. Thermal techniques such as DSC, DTA, TGA, TMA, and dilatometry will be described. Thermal processing and temperature measurement techniques will also be covered. Mechanical techniques such as viscometry, rheometry, strength/toughness testing, hardness testing, and fatigue will be covered. These thermal and mechanical techniques will be used to elucidate the relationship between properties and microstructure, relaxation mechanisms, lifetime predictions, phase transformations, chemical reactions, and synthesis.

MATE 314, Transport Processes, 3 cr, 3 cl hrs

Prerequisites: MATH 131, MATH 132; PHYS 121

Introduction to the concepts of fluid dynamics and mass and heat transfer.

MATE 350, Materials Thermodynamics, 3 cr, 3 cl hrs

Prerequisite: MATH 231, CHEM 121, PHYS 121. (ES 347 is recommended.)

The mathematical structure of thermodynamics is developed and elucidated from a transport-process-based perspective. Basic quantities such as heat and temperature are carefully defined. The conserved nature of the First-Law and the non-conserved nature of the Second Law are emphasized. The consequences of the ensuing stability-conditions are explored in the area of phase equilibrium in multicomponent mixtures. (Same as ChE 349)

MATE 351, Introduction to Polymeric Materials, 3 cr, 3 cl hrs

Prerequisites: MATE 202 or MATE 235, MATH 231 or MATH 335

Basic concepts of polymer science; polymerization reactions and mechanisms, as well as kinetics involved; polymer solutions, molecular-weight determinations, analysis and testing of polymers; structural properties of polymers; properties of commercial polymers; processing of polymers.

MATE 402, Physical Ceramics, 3 cr, 3 cl hrs

Prerequisite: MATE 301

Review of ceramic microstructures. Atomistic, microstructural, and thermodynamic origins of ceramic properties, with emphasis on the effects of atomic and structural defects and interpretation of phase diagrams.

MATE 410 Microstructural Characterization Methods and Analysis 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS122, MATE 202, MATE 235 or consent of instructor

Crystalline and non-crystalline materials are characterized using various types of scattering, diffraction, absorption and microscopy techniques. Methodologies such as x-ray diffraction, electron diffraction and microscopy are introduced for analyzing crystallographic and other structural properties of metals, ceramics, polymers and composites.

MATE 420 Biomedical Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 202 or MATE 235 or consent of instructor

This course covers the application of materials in medical devices. Mechanical properties of hard and soft tissues are reviewed. Applications of biomaterials in orthopedics are discussed with emphasis on problems of material-tissue interactions. Other biomedical materials are covered with applications in skin transplants, eye surgery, pacemakers, tissue engineering, and neural prostheses. Host responses are surveyed including adaptation, inflammation, coagulation, foreign body effects, and changes in tissue and organ functions. Methods for biological and clinical testing are highlighted. Regulatory, ethical and business issues are discussed. Students taking the graduate-level course will write an additional report proposing a new solution to an unsolved surgical problem. Shares lecture with MATE 520, with additional expectations for graduate credit.

MATE 430, Design and Analysis of Experiments, 3 cr, 3 cl hrs

Prerequisite: Senior standing

Methods of statistics and modeling important to many problems in materials science and engineering including Six Sigma. Examples are chosen from a number of actual experiences. Safety considerations and experiment design including analysis of risk, how risks may be integrated, and how formal procedures should be established. The use of information sources, such as materials safety data sheets (MSDS). (Same as ChE 463)

MATE 431, 431D, Fundamentals in Manufacturing Processes of Materials I, 3 cr, 3 cl hrs

Prerequisites: MATE 202; ES 302; and senior standing or consent of instructor

Introduction to materials design; flow theories and work of deformation; microstructure-property relationships for different materials; fracture; casting and heat-flow/mass-transfer issues; bulk deformation processing with applications to rolling and extrusion; powder metallurgy and sintering of metal and ceramic powders.

MATE 434, 434D, Phase Equilibria, 3 cr, 3 cl hrs

Prerequisites: MATE 350/ChE 349 and CHEM 331

The theoretical and practical aspects of phase equilibria of multicomponent systems will be examined in detail. The thermodynamics of these systems will be studied along with the experimental methods of determining phase equilibrium. Particular emphasis will be placed on interpretation of binary and ternary systems for metals and ceramics.

MATE 435, Mechanical Behavior of Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 202 or consent of instructor

Elasticity and plasticity; flow criteria. Strengthening mechanisms. Deformation processes. Mechanical testing of materials: tensile, hardness, fatigue, fracture, formability.

MATE 441, 441L, X-Ray Diffraction, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS 122, MATE 202 or MATE 235

Properties and generation of X-rays, X-ray diffraction phenomena. Single-crystal and powder techniques for study of structure of metals and alloys, imperfections, stress, and strain.

MATE 442, Solid State Diffusion, 3 cr, 3 cl hrs

Prerequisite: MATE 314 or ES 314

Development of the diffusion equations in solids and their solutions by analytical and numerical methods. Diffusion theory and mechanisms. Diffusion phenomena in semiconductors, metals, alloys, ionic crystals, and oxides. Thermodynamic, point-defect and defect reactions, and impurity effects. High-diffusivity paths; Electromigration (EM) in metallic films and EM measurement. Review of experimental techniques.

MATE 443, Magnetic Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 235 or consent of instructor

The origin of magnetism, theory of magnetism, comparison of diamagnetic, paramagnetic, ferromagnetic, and ferromagnetic solids. Magnetic measurements, magnetic characterization techniques, domain theory and hysteresis. Structure-processing-property relationships in magnetic materials. Applications of “hard” and “soft” magnetic materials.

MATE 445, 445D, Introduction to Composite Materials, 3 cr, 3 cl hrs

Prerequisites: ES 302 or consent of instructor

Reinforcement materials, glass, Kevlar, polyethylene, carbon, boron, silicon carbide, alumina, metallic fibers. Interface between the matrix and fiber. Polymer matrix, metal matrix, and ceramic matrix composites. Mechanism of fiber strengthening. Micromechanics and macromechanics of composite materials, their strength and fracture behavior.

MATE 446, 446D, Computer Simulation in Materials Science, 3 cr, 3 cl hrs

Prerequisite: MATH 231

Computers have become a common tool in the effort to bridge the gap between atomic and macroscopic materials properties. Examples selected from the literature are used to introduce the student to the principal techniques employed in the field. Topics covered include: polymers, metals, ceramics, magnetic materials, water, phase equilibrium, protein folding, self-assembled monolayers, gelation, the glass transition, rheology, and dielectric relaxation.

MATE 447, Optical Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 235 or consent of instructor

Review of optical phenomena: reflection, transmission, absorption, color, polarization, refraction and birefringence, and their origin in materials. Structure-processing-property relationships in optical materials including crystals, glasses, and thin films. Applications including mirrors, filters, lenses, lasers, electro-optics, detectors and fiber optics.

MATE 452, 452D, Solid State Physics for Engineers, 3 cr, 3 cl hrs

Prerequisite: Senior standing or consent of instructor

Discussion of physical properties of metals, semiconductors, and dielectrics from the viewpoint of solid-state theory. Electron dynamics, electronic transport, interaction of electromagnetic waves with solids, wave mechanics, quantum mechanics, free electron theory, band theory of solids. Application of semiconductor and quantum physics to modern electronic and opto-electronic devices.

MATE 452L, Electronic Materials Laboratory, 1 cr, 3 lab hrs

Prerequisites: MATE 235, 235L, or consent of instructor

Use of electronic measurement equipment to characterize the behavior of common circuit components: resistors, capacitors, inductors, temperature- and voltage-dependent resistors, diodes. Interpretation of electronic properties of materials.

MATE 460, Failure Analysis, 3 cr, 3 cl hrs

Prerequisite: ES 302

Failure analysis is the science of unraveling why a product failed unexpectedly. The results of the failure analysis may be used to design a better product, or as evidence in litigation. This course will cover the proper methodology for investigating a failure, the common failure modes of structures and machines, fractography, the procedure for writing a failure analysis report, and the legal implications.

MATE 466, 466D, Interfacial Phenomena, 3 cr, 3 cl hrs

Prerequisite: MATE 350 or equivalent or consent of instructor

Thermodynamics of interfaces (liquid/liquid, liquid/vapor, liquid/solid, solid/solid, solid/vapor) interfacial equilibria; interfacial free energy (surface tension measurements in liquids; specific surface free energy in solid systems); structure of solid surfaces and interfaces; properties of interfaces; case studies in ethical decision making. Shares lectures with MATE 566, but is graded separately and additional work is required at the graduate level.

MATE 470, Corrosion Phenomena, 3 cr, 3 cl hrs

Prerequisite: CHEM 122, MATE 202 or MATE 235

Theory of aqueous corrosion (thermodynamics and kinetics); forms of corrosion; corrosion testing and evaluation; designing to minimize corrosion; methods of corrosion prevention; corrosion of specific systems; case studies.

MATE 472, 472D, Advanced Transport Phenomena, 3 cr, 3 cl hrs

Prerequisite: ES 216 and 350 or MATE 314 or consent of instructor

Advanced topics in momentum, heat, and mass transfer. Newtonian and non-Newtonian fluid behavior and laminar flow problems, elementary turbulent flow concepts, energy balance applications in incompressible fluid flow, flow and vacuum production. Fourier’s law and thermal conductivity of materials, steady state and time dependent heat conduction, application in solidification, elementary convective heat transfer. Diffusivity of materials, diffusion in gases, liquids and solids and through porous media, time dependent diffusion, and interphase mass transfer.

MATE 474, Polymer Processing and Characterization, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Consent of instructor

The basics of rheology, calorimetry and mechanical testing are covered. A specific polymer is used (e.g., an epoxy) throughout the course and the processing of this polymer is covered. Students are expected to acquire a working knowledge of the instrumentation and analysis tools used in the course. These include rheometers, calorimeters, and mechanical testing. The primary analysis tool is Kaleidagraph software. (Same course as ChE 474)

MATE 479, Transmission Electron Microscopy, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: MATE 441, MATE 410, or consent of instructor

Electron optics, design and operation of TEM; specimen preparation; electron diffraction and interpretation of diffraction patterns; imaging, dynamical theory; image interpretation for perfect crystals, crystal defects, interfaces and precipitates. Use of a TEM.

MATE 480, Advanced Dislocation Theory, 3 cr, 3 cl hrs

Prerequisite: METE 327 or consent of instructor

Dislocations in isotropic continua; effects of dislocations on crystal structure; point defects and physical properties; point defects and mechanical properties; dislocation-point-defect interactions and groups of dislocations; dislocation interactions. Shares lectures with MATE 580, but is graded separately and additional work is required at the graduate level.

MATE 481, 481L, Engineering Design I, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: Senior Standing, MATE 301, MATE 351, METE 327, MATE 310, MATE 311 (BIOL 111/111L may substitute for MATE 310 or 311 for students pursuing the Biomaterials Engineering Option)

Student design teams begin a year-long capstone design project. The teams will identify project needs, establish goals, determine design requirements, produce alternate solutions, and perform detailed planning. Project initiation, periodic design reports and design reviews. Students, faculty, and distinguished visitors discuss subjects of current and/or long-range interest in various fields of materials. Undergraduate students majoring in Materials Engineering are required to take MATE 481 and MATE 481L concurrently.

MATE 482, 482L, Engineering Design II, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: MATE 481, MATE 481L

Continuation of the design projects initiated in MATE 481. The student design teams bring the projects to a successful conclusion. Economic analysis and detailed cost evaluation, use of engineering statistics in data analysis and design of experiments, preparation and presentation of final project report. Undergraduate students majoring in Materials Engineering are required to take MATE 482 and MATE 482L concurrently.

MATE 483, 483L, Scanning Electron Microscopy, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: PHYS 122 or consent of instructor

Fundamental theory and experimental techniques in scanning electron microscopy. Electron optics, electron beam interactions with solids, signal detection and processing. Chemical X-ray microanalysis. Undergraduate students majoring in Materials Engineering are required to take MATE 483 and MATE 483L concurrently.

MATE 491, Directed Study/Senior Thesis, 3 cr

Prerequisite: Senior standing or consent of instructor

MATE 500, Directed Research, cr to be arranged

Prerequisite: Graduate standing

This course may not be used to fulfill graduate degree requirements.

MATE 501, Foundations of Materials, 3cr

Prerequisite: Graduate standing

This course is designed for the Materials graduate students with undergraduate degrees from other disciplines. Fundamental elements of metals, ceramics, polymers and composites will be covered.

MATE 502, Physical Ceramics, 3 cr, 3 cl hrs

Prerequisite: MATE 301

Review of ceramic microstructures. Atomistic, microstructural, and thermodynamic origins of ceramic properties, with emphasis on the effects of atomic and structural defects and interpretation of phase diagrams. Shares lectures with MATE 402, but is graded separately, and additional work is required at the graduate level.

MATE 503, 503D, Crystal Chemistry and Crystal Physics, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Classification of elements and ions. Bonding and rules for building of structures in solids. Systematic review of the basic crystal structures of inorganic solids and their relationship with observed macroscopic properties. Introduction to crystal physics, relating measurable quantities to crystal symmetry.

MATE 504, Non-linear Dielectric Ceramics, 3 cr, 3 cl hrs

Prerequisite: MATE 235 and graduate standing; or consent of instructor

Review of polarization mechanisms and relaxation phenomena in non-linear dielectrics. New capacitor formulations (high permittivity) and "relaxor" ferroelectrics. Ferroelectric phase transitions and phenomenology. Piezoelectricity, pyroelectricity, and applications.

MATE 505, Electronic Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 235 and graduate standing; or consent of instructor

Review of electronic, atomic, and defect structures which govern electrical behavior of ceramics and metals. Bulk and printed (thick film) electronic sensors and components. Superionic conductors used in solid electrolyte batteries, and developments in new high-temperature superconducting ceramics. Polarization mechanisms and relaxation phenomena in dielectrics, with discussion of low-permittivity and microwave dielectrics.

MATE 509, 509D, Statistical Mechanics of Simple Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 350 or ChE 349 or Graduate Standing or consent of instructor

After a brief review of thermodynamics, the basics of Statistical Mechanics are presented and applied to a number of cases of interest. These include solid state heat capacity, the adsorption of gases on surfaces, Bose-Einstein statistics, blackbody radiation, magnetism, superfluidity, Fermi-Dirac statistics, the electron gas, theories of phase transitions, and the Monte Carlo method.

MATE 510, Mechanical Properties of Ordered Intermetallic Alloys, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Development of understanding of the mechanical behavior of ordered alloys and of the process of alloy development. Crystal structures, ordering phenomena, lattice defects in ordered alloys, tensile and compressive behavior, anomalous yielding, enhanced work hardening, fracture, creep and fatigue, environmental effects, alloy development strategies.

MATE 512, 512D, Electronic Thin Films: Science and Technology, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Discussion of thin-film deposition techniques (evaporation, sputtering, molecular beam epitaxy, liquid-phase epitaxy, and chemical vapor deposition), and their applications and limitations. Thin-film growth mechanism. Stress and interdiffusion in thin films. Electrical and optical properties of thin films, heterostructures, quantum wells, and superlattices.

MATE 514, 514D, Liquid State Theory, 3 cr, 3 cl hrs

Prerequisite: MATE 509, Graduate Standing or consent of instructor

An introduction to the study of many-particle systems and to the techniques of computer simulation. The statistical mechanics of simple liquids and their mixtures, with particular emphasis on the atomic origin of the structure factor and the relationships between atomic-level structure and macroscopic, thermodynamic properties.

MATE 515, Glasses and Other Complex Fluids, 3 cr, 3 cl hrs

Prerequisite: MATE 351 or consent of instructor

Complex fluids span the range between the traditional Newtonian fluid (where shear stress is proportional to strain rate) and linear response solids (where shear stress is proportional to strain). In all cases, non-trivial relaxation mechanisms introduce a range of relaxation times and extreme temperature sensitivity in the materials' properties. Glasses are the most dramatic examples of this class of materials although all polymeric materials show complex behavior under temperature and time scales in typical applications. This course introduces the techniques used to quantify the thermal and temporal response of common complex fluids focusing primarily on rheometry and calorimetry. In addition, theories linking evolving microstructures are employed to explain the observed macroscopic responses.

MATE 516, Biomimetic Materials, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

An overview of the field of biomimetics: the achievement of unusual materials properties or processes by mimicry of various aspects of biological systems. Mimicry of natural structural design; biomimetic materials processing; "artificial photosynthesis"; biomolecular electronics; and biomimetic catalysis. Interdisciplinary studies.

MATE 520 Biomedical Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 202 or MATE 235 or consent of instructor

This course covers the application of materials in medical devices. Mechanical properties of hard and soft tissues are reviewed. Applications of biomaterials in orthopedics are discussed with emphasis on problems of material-tissue interactions. Other biomedical materials are covered with applications in skin transplants, eye surgery, pacemakers, tissue engineering, and neural prostheses. Host responses are surveyed including adaptation, inflammation, coagulation, foreign body effects, and changes in tissue and organ functions. Methods for biological and clinical testing are highlighted. Regulatory, ethical and business issues are discussed. Students taking the graduate-level course will write an additional report proposing a new solution to an unsolved surgical problem. Shares lecture with MATE 420, with additional expectations for graduate credit.

MATE 530, 530D, Design and Analysis of Experiments, 3 cr, 3 cl hrs

Methods of statistics and modeling important to many problems in materials science and engineering including Six Sigma. Examples are chosen from a number of actual experiences. Safety considerations and experiment design including analysis of risk, how risks may be integrated, and how formal procedures should be established. The use of information sources, such as materials safety data sheets (MSDS). Shares lectures with MATE 430, but is graded separately, and additional work is required at the graduate level.

MATE 531, 531D, Fundamentals in Manufacturing Processes of Materials I, 3 cr, 3 cl hrs

Prerequisite: MATE 202 or equivalent; ES 302 or equivalent

Introduction to materials design; flow theories and work of deformation, microstructure-property relationships for different materials; fracture; casting and heat-flow/mass-transfer issues; bulk deformation processing with applications to rolling and extrusion; powder metallurgy and sintering of metal and ceramic powders. Shares lectures with MATE 431, but is graded separately, and additional work to include learning manufacturing software, as well as a detailed research paper, is required at the graduate level.

MATE 534, Introduction to Solidification and Phase Transformations, 3 cr, 3 cl hrs

Prerequisites: MATE 350; METE 327

Corequisite: MATE 442

Thermodynamic considerations and phase diagrams (review); influence of interfaces on equilibrium; influence of interfaces and of strain energy on microstructure and kinetics; solidification of single-component and multicomponent systems; ingots, castings, and weldings; sol-gel processing; diffusional transformations in solids: precipitation, eutectoid transformations, massive transformations, and ordering; diffusionless transformations in solids: martensitic transformations. Shares lectures with MATE 434 (formerly 444), but is graded separately, and additional work is required at the graduate level.

MATE 540, 540D, Electrochemical Techniques & Process, 3 cr, 3 cl hrs

Prerequisites: Upper division or graduate student standing

This course is an overview of the growing field of electrochemistry, and the many electrochemical techniques and processes. The lectures and assignments will review the theory and the science of batteries, electroplating, fuel cells, electrocatalysis, electro-refining, corrosion, bioelectrochemistry, and organic electrosynthesis. In addition to the applications, the electrochemical techniques will also be introduced, including open circuit potentials, linear polarization, potentiodynamic polarization, cyclic voltammetry, zeta potentials, electrochemical impedance spectroscopy, and photoelectrochemistry.

MATE 541, Advanced Physical Metallurgy, 3 cr, 3 cl hrs

Prerequisites: METE 327; or consent of the instructor

Application of thermodynamic principles to formation and stability of alloy systems. Recrystallization. Precipitation hardening. Physical metallurgy of steels, aluminum, rapidly solidified alloys, and quasi-crystals.

MATE 543, Advanced Mechanical Metallurgy, 3 cr, 3 cl hrs

Prerequisites: MATE 435

Theory of elasticity/plasticity; dislocation theory; strengthening mechanisms; tensile testing; fracture and related failure phenomena; principal features of fatigue and creep; metalworking; related strain rate phenomena, including shock deformation and high energy rate forming.

MATE 544, Strengthening Mechanisms, 3 cr, 3 cl hrs

Prerequisite: MATE 435 or consent of instructor

Application of dislocation theory to precipitation, dispersion and solution hardening; yielding; strain aging; Hall-Petch phenomena and strengthening by grain refinement; strengthening by dislocation substructures; work hardening; strength of martensite; fiber-reinforced composites; production of strong microstructures.

MATE 545, Micromechanics of Fracture, 3 cr, 3 cl hrs

Prerequisite: MATE 435 or equivalent or consent of instructor

Analysis of criteria for crack initiation and propagation leading to structural failure; study of fracture mechanics starting with Griffith theory for ideally brittle materials through plane strain and ultimately elastic-plastic toughness phenomena. Effects of geometry, rate, environment, and microstructure will be considered as related to micromechanisms of fracture (cleavage, ductile fracture, fatigue, stress corrosion cracking).

MATE 548, Advanced Composite Materials, 3 cr, 3 cl hrs

Prerequisite: MATE 445 or consent of instructor

Reinforcements, their fabrication and properties. Matrix materials and their characteristics. Interfaces in various types of composites. Micromechanics of composites; macromechanics of composites. Failure processes in composites. Designing with composites. Specific important composite systems, their fabrication, properties, and applications.

MATE 549, Nano-Materials, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Physical basics of nanosystems, physics and chemistry of nanostructure synthesis and fabrication, semiconductor nanostructures, magnetic nanostructures and spintronics, molecular nanostructures, electron transport in nanosystems, optical effects in nanosystems, nanomachines, nanoscale biological assemblies, nanocomposite materials.

MATE 554, Scattering Techniques, 3 cr, 3 cl hrs

Prerequisite: MATE 351 or consent of instructor

Application of scattering techniques to the characterization of polymeric materials, ranging from polymer solutions to melts or composites. Molecular motion of polymers in solutions and melts, Flory-Huggin theory, phase separation. Fundamentals and applications of scattering techniques to polymeric materials. Dynamic light scattering, laser light scattering neutron scattering, X-ray scattering.

MATE 560, 560D, Failure Analysis, 3 cr, 3 cl hrs

Prerequisite: ES 302 or consent of instructor

Failure analysis is the science of unraveling why a product failed unexpectedly. The results of the failure analysis may be used to design a better product, or as evidence in litigation. This course will cover the proper methodology for investigating a failure, the common failure modes of structures and machines, fractography, the procedure for writing a failure analysis report, and the legal implications. Shares lecture with MATE 460, but is graded separately, and additional graduate-level work is required.

MATE 563, Radiation Effects in Materials, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Fundamentals of radiation damage (energetic particles and energy dissipation, atomic displacements and cascades, evolution of damage); material-dependent radiation-damage phenomena (at atomic, microstructural, and macrostructural levels); applications (swift-ion irradiation effects, ion-beam modification of materials, nanostructure design via irradiation, nuclear fuels and waste forms, radiation detectors and dosimeters, solar and galactic cosmic particles).

MATE 564, 564D, Nano-Optics, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

Review of Nano-Optics—an emerging field, rapidly developing as a part of nanoscience and nanotechnology requiring tools and techniques for fabrication, manipulation and characterization at nanoscale. The class covers theoretical foundations on propagation and focusing of optical fields; methods of nanoscale optical microscopy: near-field optical probes and nanoscale distance control; features of optical interaction in nanoscale environments. Modern applications of nano-optics including quantum emitters, photonic crystals and resonators, surface plasmons structures and devices, will be discussed in the frames of this class.

MATE 565, 565D, Catalyst Characterization Techniques, 3 cr, 3 cl hrs

Prerequisite: ChE 349/MATE 350 and/or CHEM 331/332 or consent of instructor

The course provides an overview of techniques used to characterize catalytic materials including data analysis and linking physical and chemical properties to catalytic activity at the laboratory and process level. Topics include x-ray methods, neutron scattering methods, physical adsorption, chemical adsorption, temperature programmed techniques, photoelectron spectroscopy, vibrational spectroscopy, and electron microscopy. A research project is required.

MATE 566, Interfacial Phenomena, 3 cr, 3 cl hrs

Thermodynamics of interfaces (liquid/liquid, liquid/vapor, liquid/solid, solid/solid, solid/vapor); interfacial equilibria; interfacial free energy (surface tension measurements in liquids; specific surface free energy in solid systems); structure of solid surfaces and interfaces; properties of interfaces.

MATE 567, Dynamic Deformation of Solids, 3 cr, 3 cl hrs

Prerequisite: Graduate standing

Elastic waves. Plastic waves. Shock waves (Rankine-Hugoniot equations and more advanced treatments incorporating materials strength). Wave interactions and attenuation (including spalling). Spherical and cylindrical waves. Impact; Gurney equation. Principles of detonation.

MATE 568, Material Behavior at High Strain Rates, 3 cr, 3 cl hrs

Prerequisite: MATE 567

Mechanical properties of materials as a function of strain rate. Dislocation dynamics at high velocities. Structural changes introduced by shock waves: phase transformations, point defects, line defects, interfacial defects. Dislocation models for shock front. Materials aspects of adiabatic shear localization, spalling, dynamic deformation. Shock modification of ceramics.

MATE 569, 569D, Fuel Cell Technology, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

The principles of fuel cell technology, including classification of fuel cells and operating mechanisms. Analysis of underlying thermodynamics and physical factors which govern fuel cell performance and efficiency. Cell components and integrative cell design.

MATE 570, 570D, Corrosion Phenomena, 3 cr, 3 cl hrs

Prerequisite: CHEM 122 and Graduate Standing

Theory of aqueous corrosion (thermodynamics and kinetics); forms of corrosion; corrosion testing and evaluation; designing to minimize corrosion; methods of corrosion prevention; corrosion in specific systems; case studies. Shares lecture with MATE 470, but is graded separately and additional graduate-level work is required.

MATE 575, 575D, Introduction to Nano Materials, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of instructor

An introduction to physical basics of nanosystems, physics and chemistry of nanostructure synthesis and fabrication. Other topics include: semiconductor nanostructures, magnetic nanostructures and spintronics, molecular nanostructures, electron transport in nanosystems, optical effects in nanosystems, nanomachines, nanoscale biological assemblies, nanocomposite materials.

MATE 576, Drug Delivery Techniques, 3 cr, 3 cl hrs

Prerequisite: Senior or graduate standing or consent of instructor

Focus is on current developments in drug delivery techniques, with only a brief discussion of common clinical techniques. The first portion of the class focuses on various delivery mechanisms and the tools needed to validate successful targeted drug delivery (both in vitro, in vivo and diagnostic tools). The second part of the course focuses on current developments in drug delivery based on published research articles. Students will read, digest, and critically analyze scientific work from leading research laboratories. Students will also gain valuable communication tools, as each student will present an article of interest to the class. Finally, the third part of the course focuses on important materials characterization methods such as biological sample prep, SEM, TEM, DSC, Flow Cytometry, Fluorescence Microscopy, ELISA Assays. . Shares lecture with ChE 476 but is graded separately and additional graduate-level work is required.

MATE 579, Advanced Electron Microscopy, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: MATE 479 or MATE 483; graduate standing

Advanced topics in transmission electron microscopy. In-situ studies of deformation and fracture processes, environmental effects, and radiation damage. High-resolution electron microscopy, weak-beam techniques, scanning transmission electron microscopy, electron microdiffraction. Analytical electron microscopy; electron energy loss spectroscopy and energy-dispersive analysis of X-rays; instrumentation, techniques, quantitation, applications.

MATE 580, Advanced Dislocation Theory, 3 cr, 3 cl hrs

Prerequisite: MATE 435 or consent of instructor

Dislocations in isotropic continua; effects of dislocations on crystal structure; point defects and physical properties; point defects and mechanical properties; dislocation-point-defect interactions and groups of dislocations; dislocation interactions. Shares lectures with MATE 480, but is graded separately, and additional work is required at the graduate level.

MATE 581, 581D, Directed Study, cr to be arranged

Study under the guidance of a member of the department. In general, subject matter will supplement that available in the other graduate course offerings in metallurgy or materials engineering.

MATE 590, Independent Study, cr to be arranged

The student must clearly demonstrate the ability to organize and pursue research. A written final report and public oral presentation is required.

MATE 591, Thesis (master's program), cr to be arranged**MATE 592, 592D, Materials Engineering Graduate Seminar, 1 cr, 1 cl hrs**

Must be taken S/U

Prerequisite: Graduate standing or consent of instructor

Seminar presentations by students, faculty and outside speakers. Discussion of topics of technical interest in materials science and engineering and related fields.

MATE 595, Dissertation (doctoral degree program), cr to be arranged

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

MATE 599, 599D, Special Topics, cr to be arranged

Lectures in new or advanced areas of materials.

Metallurgical Engineering Courses:

METE 326, Introduction to Process Metallurgy, 3 cr, 3 cl hrs

Prerequisite: CHEM 121

Corequisite: MATH 132

Introduction to stoichiometric computations. Calculations of energy and material balance. Elementary process analysis and reactor design. Single-phase and multi-phase systems. (Same as ChE 326)

METE 327 Introduction to Physical Metallurgy, 3 cr, 3 cl hrs

Prerequisite: MATE 202

Mechanisms of deformation and fracture in metals. Binary phase diagrams. Phase transformations, age hardening, heat treatment of steels, TTT diagrams, CT diagrams, martensitic transformation, shape-memory effects. Common ferrous and non-ferrous alloys.

METE 434, Introduction to Dislocation Theory, 3 cr, 3 cl hrs

Prerequisite: METE 327 or consent of instructor

An introduction to elasticity and the theory of plastic flow in materials. Geometrical and crystallographic features of dislocations, elastic equations of dislocations in crystals. Partial dislocations and stacking faults. Dislocation interactions and multiplication.

METE 491, Directed Study/Senior Thesis, 3 cr

Prerequisite: Senior standing or consent of instructor

Faculty Research Interests

Burleigh—Corrosion Mechanisms, Alloy Design, Coatings for Corrosion Prevention and Electrochemical Processes

Fuierer—Electronic/Functional Ceramics, Ionic Conductors for Fuel Cells and Sensors, Photovoltaics, Grain-Oriented Ceramics, and Aerosol Deposition of Ceramic Thick Films

Henneke—Nanomaterial Synthesis and Characterization, Nano-Structured Optical Waveguides, and Interfacial Phenomena

Kalugin — Optoelectronics and Nonlinear Optics, Nanostructures and Nanotechnology, TeraHz Lasers and Photodetectors, Solid State Physics of Nanostructures, and Semiconductor Materials and Devices

Majumdar — Structure-Property Relations in Materials, Processing of Metals and Composites, SMAs, Fatigue, Creep, Fracture

McCoy—Statistical Theory, Atomistic Simulation, Rheology, Glass Transition, Thin Films

G. Bond — Electron Microscopy, Hydrogen Effects, Metal Hydrides, Radiation Damage, Biomimetic Materials and Processing, Carbon Dioxide Sequestration, and Controlled Crystallization

Leclerc—Catalysis, Reactor Design, Alternative Fuels

Tartis—Biomedical Engineering, Biomaterials, Targeted Drug Delivery, Ultrasound Mediated Drug Release

Teare—Experimental Adaptive Optics, Directed Energy

Mechanical Engineering

Professor: Ford

Associate Professors: Bakhtiyarov, Ghosh, Lim, Ostergren, Yilmaz, Zagrai (Chair of the Department)

Assistant Professors: Grow, Hargather, Kimberley, Ryu, Wei

Visiting Assistant Professor: Wei

Adjunct Faculty: DeChant, Dinwiddie, Fakhimi, Field, Higgins, Kennedy, Langley, Marcy, A. K. Miller, O'Malley, Rivera, Romero, Ruff, Stofleth, Stone, Westpfahl

Emeritus Faculty: A. Miller

Degrees Offered: B.S. in Mechanical Engineering; M.S. in Mechanical Engineering

The Department of Mechanical Engineering at New Mexico Tech administers the following programs:

- Bachelor of Science in Mechanical Engineering
- Master of Science in Mechanical Engineering
 - Specialization in Explosives Engineering
 - Specialization in Fluid and Thermal Sciences
 - Specialization in Mechatronics Systems and Robotics
 - Specialization in Solid Mechanics

Program Educational Objectives

The Department of Mechanical Engineering at New Mexico Tech will produce Bachelor of Science graduates who are independent thinkers, taking ownership in identifying problems and determining effective solution strategies in a timely manner. Following working experience after graduation, they will:

1. Be employed successfully in government laboratories, graduate schools, industry, or other areas of the profession
2. Have an understanding of the importance of life-long learning such that they seek personal and professional growth.
3. Have achieved a noteworthy level of workplace responsibility.

Undergraduate Programs

Bachelor of Science in Mechanical Engineering

Mechanical engineering is considered to be one of the cornerstone engineering disciplines and is perhaps the broadest of all engineering disciplines. Mechanical engineers are found in every sector of our technology-based economy. Mechanical engineers find careers in (to name just a few): electric power generation and distribution; petroleum exploration, production and refining; automotive, truck and bus manufacturing; light and heavy rail transportation and manufacturing; agricultural equipment manufacturing; commercial and industrial construction industries; aeronautical design and manufacturing; national defense industries; semiconductor manufacturing; biomedical technology; petrochemical process industries; basic materials extraction and refining industries.

The undergraduate mechanical engineering program is very broad in its scope, yet it contains sufficient depth to ensure competency in the discipline. Mechanical engineering students must take a heavy load of science and mathematics as prerequisites for their engineering science courses.

Mechanical engineers in industry must be able to interact with many engineering disciplines, so they are required to take courses in other engineering disciplines. Also, because mechanical engineers design and manufacture components and systems, they are required to take courses that emphasize the engineering design/definition process. The mechanical engineering graduate engineer should be well equipped to undertake a professional engineering career in any technology that he or she chooses.

The mechanical engineering program at New Mexico Tech offers the students hands-on laboratory experience in fluid and thermal sciences, mechanics of materials, vibrations, mechatronics, dynamic systems and controls, instrumentation, and measurement. Junior and senior mechanical engineering students work on design projects for two years that range from the Baja SAE® vehicles to aerospace aircraft design.

Minimum credit hours required—136

In addition to the General Education Core Curriculum (page 7 with MENG 341 substituted for ENGL 341), the following courses are required:

- ES 111 (3), 201 (3), 216 (3)*, 302 (3), 303 (3), 316 (3), 332 (3), 347 (3), 350 (3)
- MENG 110 (1), MENG 110L (1), MENG 302L (1), 304 (3), 305 (3) 351L(1), 352L (1), 341(3), 381 (2), 382 (2), 405 (2), 405L (1), 421 (3), 431 (3), 441 (3), 451 (3), 481 (3), 482 (3), 483 (2) & 483L (1)
- MATE 202 & 202L (4)
- MATH 131 (4), MATH 132 (4), MATH 231 (4), MATH 335 (3) , MATH 337 (3)
- Technical Electives: Three hours from upper-division courses chosen by the student with the faculty advisor's approval.

* or MENG 216(3)

Credit for MATH 103, pre-calculus, and MATH 104, trigonometry, is not allowed for mechanical engineering students.

Courses used for the degree, including the General Education Core Curriculum, may not be taken on an S/U basis except for two courses in Humanities and/or Social Science.

Mechanical engineering majors must take the Fundamentals in Engineering (FE) exam as a requirement for graduation. Passing this exam is a major step in the process of attaining professional registration. It is **strongly** recommended that the exam be taken in semester 7, before the graduation semester (semester 8).

It is strongly recommended that all Mechanical Engineering students follow the sample curriculum.

Sample Curriculum for the Bachelor of Science in Mechanical Engineering

Semester 1

- 3 ENGL 111 (college English)
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 2 MENG110 & 110L (intro.)
- 3 Social Science
- 16 Total credit hours

Semester 2

- 3 ENGL 112 (college English)
- 4 MATH 132 (calculus)
- 5 PHYS 121 & 121L (general)
- 3 ES 111 (computer engr.)
- 3 Humanities
- 18 Total credit hours

Semester 3

- 3 Social Science
- 4 MATH 231 (calculus)
- 4 CHEM 122 & 122L (general)
- 3 ES 201 (statics)
- 4 MATE 202 & 202L (intro to materials)
- 18 Total credit hours

Semester 4

- 3 MATH 335 (ordinary differential equations)
- 5 PHYS 122 & 122L (general)
- 3 MATH 337 (engineering math)
- 3 MENG 216/ES 216 (fluid mechanics)
- 3 ES 302 (mechanics of materials)
- 1 MENG 302L (mechanics of materials lab)
- 18 Total credit hours

Semester 5

- 3 MENG 305 (engineering analysis)
- 3 ES 303 (dynamics)
- 3 MENG 304 (advanced strength of materials)
- 3 ES 347 (thermodynamics)
- 2 MENG 381 (junior design)
- 3 MENG341 (mechanical engineering tech writing)
- 17 Total credit hours

Semester 6

- 3 ES 332 (electrical circuits)
- 3 MENG 421 & 421L (finite element analysis & design)
- 1 MENG 351L (fluids lab)
- 1 MENG 352L (instrumentation and measurements lab)
- 2 MENG 382 (junior design)
- 3 ES316 (engineering economics)
- 3 ES 350 (heat & mass transfer)
- 16 Total credit hours

Semester 7 (Take FE exam)

- 2 MENG 405 (dynamic systems & controls)
- 1 MENG 405L (dynamics systems & controls lab)
- 3 MENG 451 (machine design)
- 3 MENG 481 (senior design)
- 3 MENG 441 (dynamics & vibration)
- 3 Humanities
- 3 Social Science
- 18 Total credit hours

Semester 8

- 3 MENG 431 (fluid/thermal systems)
- 3 MENG 483 & 483L (mechatronics)
- 3 MENG 482 (senior design)
- 3 Technical Elective
- 3 Humanities/Social Science
- 15 Total credit hours

Minor in Mechanical Engineering

Minimum credit hours required – 18

The following courses are required:

At least eighteen (18) credit hours of ES or MENG courses and/or labs beyond those required for major. These courses and labs are subject to the approval of the Mechanical Engineering Minor Advisor.

Minor in Aerospace Engineering

Minimum credit hours required – 18

The following courses are required:

AE 311, Aerodynamics I, 3 cr, 3 cl hrs

AE 412, Aerospace Systems, 3 cr, 3 cl hrs

AE Elective, 3 cr, 3 cl hrs

One course from:

- AE 313, Orbital Mechanics, 3 cr, 3 cl hrs
- AE 414, Aerospace Structures, 3 cr, 3 cl hrs

Two courses from:

- AE 313, Orbital Mechanics, 3 cr, 3 cl hrs
- AE 318, Experimental Methods in Aerodynamics, 2 cr, 2 cl hrs
- AE 318L, Experimental Methods in Aerodynamics Lab, 1 cr, 3 lab hrs
- AE 414, Aerospace Structures, 3 cr, 3 cl hrs
- AE 415, Aerodynamics II, 3 cr, 3 cl hrs
- AE 416, Aircraft Flight Dynamics and Controls, 3 cr, 3 cl hrs
- AE 417, Aerospace Propulsion, 3 cr, 3 cl hrs
- AE 418, Structural Dynamics in Aerospace Engineering, 3 cr, 3 cl hrs

Minor in Biomedical Engineering

Minimum credit hours required – 19

The following courses are required:

BIOL 111, 111L, General Biology, 4 cr, 3 cl hrs, 2 lab hrs

BIOL 331, Cell Biology, 3 cr, 3 cl hrs

BIOL 351, Physiology I, 3 cr, 3 cl hrs

BIOL 352, Physiology II, 3 cr, 3 cl hrs

Two courses from:

- MATE 351, Introduction to Polymeric Materials, 3 cr, 3 cl hrs
- MENG 460, Introduction to Biomedical Engineering, 3 cr, 3 cl hrs
- MENG 465, Biorheology, 3 cr, 2 cl hrs, 3 lab hrs
- MATE 516, Biomimetic Materials, 3 cr, 3 cl hrs
- CHE 473, Polymer Materials Engineering, 3 cr, 3 cl hrs
- MENG 576, Biomedical Mechatronics, 3 cr, 3 cl hrs
- MENG 489, Special Topics in Biomedical Engineering, 3 cr, 3 cl hrs

Senior Design Project:

Students, who are interested in a minor in Biomedical Engineering, will do their Junior/Senior Design Project in the Biomedical Engineering field. This is an opportunity for them to implement their learning in the mechanical engineering and life sciences fields to tackle a particular problem in the biomedical engineering field.

Minor in Explosives Engineering

Minimum credit hours required – 18

The following courses are required:

EXPL 311/MENG 545, Introduction to Explosives Engineering, 3 cr, 3 cl hrs

EXPL 412/MENG 549, Wave Propagation, 3 cr, 3 cl hrs

EXPL Elective, 3 cr, 3 cl hrs (subject to the approval of the Explosives Engineering Minor Advisor)

One course from:

- EXPL 314, Theory and Application of Pyrotechnic, 3 cr, 3 cl hrs
- EXPL 413/MENG 589, Impact Dynamics, 3 cr, 3 cl hrs

Two courses from:

- EXPL 314, Theory and Application of Pyrotechnic, 3 cr, 3 cl hrs
- EXPL 316, Energetic Material Chemistry, 3 cr, 3 cl hrs
- EXPL 317, Energetic Material Safety, 3 cr, 3 cl hrs
- EXPL 320, Explosives Technology and Applications, 3 cr, 3 cl hrs
- EXPL 413/MENG 589, Impact Dynamics, 3 cr, 3 cl hrs
- EXPL 414/ChE 475, Explosives Surety, 3 cr, 3 cl hrs
- EXPL 415/MENG553, Computer Modeling of Detonations, 3 cr, 3 cl hrs
- EXPL 418, Shock Physics and Structural Response to Blast, 3 cr, 3 cl hrs
- EXPL 419, Experimental and Diagnostic Techniques, 3 cr, 3 cl hrs

Graduate Program

Department Requirements for the Master of Science in Mechanical Engineering

The Mechanical Engineering Department administers the Master of Science in Mechanical Engineering degree for those students wanting to pursue an advanced degree in mechanical engineering. The degree may be earned with a thesis or independent study option. Students selecting the independent study option must complete one additional three credit elective course. There are currently four areas of specialization for this degree:

- Specialization in Explosives Engineering
- Specialization in Fluid and Thermal Sciences
- Specialization in Mechatronics Systems & Robotics
- Specialization in Solid Mechanics

Students must take MENG 585 each semester offered if the student is in residence. Distance-education students and part-time on-campus students are required to take two semesters of MENG 585. Only one credit of MENG 585 may be used to fulfill degree requirements. MENG 585 must be taken for a letter grade if used to fulfill degree requirements.

Requirements

A minimum of 30 credit hours is required for the Master of Science in Mechanical Engineering .

- Core Specialization Courses— at least 12 credit hours from the selected specialization listed below:
 - *Specialization in Explosives Engineering core classes:* MENG 545, Introduction to Explosives Engineering; MENG 546, Detonation Theory, MENG 549, Wave Propagation; MENG 550, Advanced Explosives Engineering; MENG 575, Advanced Engineering Mathematics.
 - *Specialization in Fluid and Thermal Sciences core classes:* MENG 556, Compressible Fluid Flow; MENG 575, Advanced Engineering Mathematics; MENG 577, Advanced Fluid Mechanics; MENG 578, Advanced Thermodynamics; MENG 579, Advanced Heat Transfer; MENG 580, Computational Fluid Dynamics and Reactive Flow.
 - *Specialization in Mechatronics Systems and Robotics core classes:* MENG 541, Vibrations in Elastic Continuum; MENG 544/EE 544, Modern Control Theory; MENG 548/EE 548, Manipulator Based Robotics; MENG 551, Sensor Technology; MENG 575, Advanced Engineering Mathematics; MENG 576, Biomedical Mechatronics.
 - *Specialization in Solid Mechanics core classes:* MENG 504, Advanced Mechanics of Materials; MENG 515, Theory of Elasticity; MENG 516, Plates and Shells; MENG 517, Advanced Finite Element Method; MENG 520, Fracture Mechanics; MENG 524, Continuum Mechanics; MENG 541, Vibration in an Elastic Continuum; MENG 583, Engineering Mechanics of Composite Structures.
- Elective Courses—6 credit hours of graduate level MENG courses. The advisory committee may allow for a maximum of 3 credits of out-of-department graduate level coursework hours to apply to the elective course requirement.
- Out-of-Department courses—6 credit hours of approved upper-division or graduate course work from another department. The advisory committee may determine that a student's previous academic experience has provided breadth and may recommend modification of this requirement.
- MENG 591, Thesis (6 credit hours) or MENG 590, Independent Study (3 credit hours) — A student must prepare and submit a thesis to his/her advisory committee for approval in accordance with the general requirements of the graduate school, or complete an independent study with accompanying report.

Aerospace Engineering Courses

AE 311, Aerodynamics I, 3 cr, 3 cl hrs

Prerequisites: MENG 216/ES 216

Fundamental concepts of aerodynamics, equations of compressible flows, irrotational flows and potential flow theory, singularity solutions, circulation and vorticity, Kutta-Joukowski theorem, thin airfoil theory, finite wing theory, slender body theory, subsonic compressible flow and Prandtl-Glauert rule, supersonic thin airfoil theory, introduction to performance, basic concepts of airfoil design

AE 313, 313D, Orbital Mechanics, 3 cr, 3 cl hrs

Prerequisites: PHYS 122 or 132, MATH 332 or MENG 305

This is a first upper-division course covering the Newtonian mechanics of orbits. Applications include ballistic missiles, satellites, and lunar and interplanetary orbits. (Same as PHYS 313.)

AE 318, Experimental Methods in Aerodynamics, 2 cr, 2 cl hrs

Prerequisite: ES 216/MENG 216

Experimental approach to problem solving and validation of theoretical/computational methods. Uncertainties in measurement. Review of fundamental equations of fluid dynamics, properties of gases and liquids, similarity laws. Wind tunnels, water channels, simulation of phenomena in processing equipment. Pressure sensors, including optically-reactive surface paint. Measurement of skin friction by direct force sensors, Preston and Stanton-tubes, diffusion analogies, liquid crystals. Flow visualization with laser light sheet; Schlieren, shadowgraph and interferometric methods. Future trends; flow control, impact of microelectronic sensors and actuators.

AE 318L, Experimental Methods in Aerodynamics Lab, 1 cr, 3 lab hrs

Corequisite: AE318

Laboratory demonstrations and exercises using available instrumentation in Mechanical Engineering Department.

AE 412, 412D, Aerospace Systems, 3 cr, 3 cl hrs

Prerequisites: ES 111; MATH 335; MENG 305

Corequisites: MENG 405, 451; EE 341 for EE majors or consent of instructor

The course explores formulation, development and implementation of a comprehensive approach to the design, analysis, and life-cycle cost management of highly complex, often adaptive systems. An appreciation for the strength of integrated, multidisciplinary skills, within a structured framework for concept development is a desired outcome of the course. A number of case studies are examined as leading examples for completion of a final class project in systems conceptualization and development management.

AE 414, 414D, Aerospace Structures, 3 cr, 3 cl hrs

Prerequisites: MENG 304, MENG 305

Behavior, analysis and design of discrete and continuous plates and shells, membrane and bending behavior, numerical methods of solution, Composite structures, Macro-mechanics to Structural design and development. Development of analytical procedures for determining material properties. Effective experimental methods and prediction of structural behavior.

AE 415, 415D, Aerodynamics II, 3 cr, 3 cl hrs

Prerequisites: AE 411

The course is covering advanced aerodynamic theories and their application. Includes airfoil shape, drag, velocity, lift, thrust, stability and control. Also included are advanced principles of performance including airplane capabilities and limitations, performance design criteria, load factors, weight and balance, comparative analysis of aircraft and aircraft certification.

AE 416, 416D, Aircraft Flight Dynamics and Controls, 3 cr, 3 cl hrs

Prerequisites: ES 332, MATH 254 or equivalent, MATH 335, MENG405, AE 411, AE 412

The application of aerodynamic surfaces to determine the trajectory and the attitude of flight vehicles involves knowledge of the forces and moments applied to the vehicle from the surrounding media in subsonic, transonic and supersonic flow regimes. Methods of either specifying, or estimating the performance parameters of a flight vehicle, operating in a particular velocity range are introduced, including the critical factors in determining the size, shape and placement of control surfaces, and the forces or torques required to reliably and accurately position such surfaces in desired states. Time-domain methods are taught for simulating flight vehicles and synthesizing robust, stable control schemes.

AE 417, 417D, Aerospace Propulsion, 3 cr, 3 cl hrs

Prerequisites: ES 216/MENG 216, ES 347

Aerospace propulsion can be classified into four categories: propeller, jet, ramjet and rocket propulsion. Among them gas turbine engines and jet propulsion are the essentials for modern aircraft. In this course, the fundamentals of different propulsion systems will be first introduced. Then the course focus will be on gas turbine engines. The material can be divided into four parts: (1) review of thermodynamics and compressible flow; (2) one-dimensional gas dynamics analysis of gas engine performance; (3) analysis and performance of air breathing propulsion system; and (4) the analysis and design of gas turbine engine components, e.g. inlets, nozzles, turbomachinery (compressors, turbines, turbofan, turbopropeller) and combustors. Further, the fundamentals of ramjet and rocket propulsion will be also discussed in this course.

AE 418, Structural Dynamics in Aerospace Engineering, 3 cr, 3 cl hrs

Prerequisites: MATH 231, ES 302, ES 303, AE 414.

This course explores structural dynamic topics covering a broad range of aerospace applications. Vibration of single and multi-degree-of-freedom systems is reviewed in the context of modeling the aerospace structural systems. Essential structural elements – bars, beams, and plates are addresses in the dynamics of continuous systems section. Structural response to transient, shock, and random loads is discussed and practical aspects of dynamic testing are presented.

AE 420, 420D, Compressible Fluid Flow, 3 cr, 3 cl hrs

Prerequisites: ES 216, ES 347, ES 350, MATH 335

Explanation of the physical phenomena encountered in compressible flow by providing practical applications and examples. Provide the knowledge and understanding of the basic fundamentals of compressible flow and gas dynamics.

AE 489, 489D, Special Topics in Aerospace Engineering, 3 cr, 3 cl hrs

AE 491, Directed Study, cr to be arranged

Explosives Engineering Courses:**EXPL 189 - Beginning Explosives Engineering, 2 cr, 2 cl hrs**

Prerequisites: none

This course will introduce the student to the subjects of pyrotechnics and explosives and encompasses subjects including basic combustion chemistry, the physical chemistry of energetic materials, and some test instrumentation. This course also will include a design project.

EXPL 189 - Beginning Explosives Engineering Lab, 3 lab hrs

Prerequisites: none

This course is based primarily in the laboratory, however, two days will be spent at the Energetic Materials Research and Testing Center working with high explosives

EXPL 311, Introduction to Explosives Engineering, 3 cr, 3 cl hrs

Prerequisites: CHEM 122 and 122L; PHYS 122 and 122L; ES 111 or CS111; ES347 or ES350; or consent of instructor

Introduction to the broad field of explosives science and technology. Basic organic chemistry, decomposition reactions, properties of explosives, thermodynamics of explosives, shock wave theory, detonation theory, initiators, Gurney equations, blast effects and demolition.

EXPL 314 Theory and Application of Pyrotechnic, 3 cr, 3 cl hrs

Prerequisite: EXPL 311

Fundamentals of basic concepts of pyrotechnic. Thermo-mechanical/chemical aspects of pyrotechnics, formulation and mixing of pyrotechnic mixtures, application of pyrotechnic including illumination, tracers, incendiaries, delays, etc.

EXPL 316 Energetic Material Chemistry, 3 cr, 3 cl hrs

Prerequisite: EXPL 311

An introduction to the chemical aspect of energetic materials. Based on basic/advanced chemical and thermo-chemical concepts and dynamics, understand the characteristic and typical properties of energetic materials.

EXPL 317 Energetic Material Safety, 3 cr, 3 cl hrs

Prerequisite: EXPL 311

Development of the concept of detonation process or Detonation-Deflagration Transition (DDT) mechanics. Analysis of the thermo-dynamic behavior of explosives, hydro hot-spot theory, shock initiation, explosives cook-off, explosive sensitization.

EXPL 320 Explosives Technology and Applications, 3 cr, 3 cl hrs

Prerequisite: EXPL 311

Focus on the application of explosives mechanics. Fundamentals of explosive welding/cutting, shaped charges, explosive-driven flux-compression generators, spallations, explosives initiation methods, explosives applied testing methods, etc.

EXPL 412, Wave Propagation, 3 cr, 3 cl hrs

Prerequisites: EXPL 311 and MATH 335; or consent of instructor

An in-depth study of the propagation of waves in various media. The derivation and application of the Rankine-Hugoniot jump equations. The concept of the rarefaction wave and various wave interactions. Derivation and application of the Mie-Gruneisen equation of state. The differential form of the conservation equations, as well as some numerical solutions for simple cases. Shares lecture with ME/MENG 549, with additional expectations for graduate credit.

EXPL 413 Impact Dynamics, 3 cr, 3 cl hrs

Prerequisites: EXPL 412

A specialized but very important branch of engineering mechanics deals with the collision of multiple bodies throughout a broad range of relative velocities. The physical phenomenon during impact and subsequent response of each of the bodies is dependent on the mechanical material properties of each, the impact velocities, and the relative size and orientation of each of the bodies. Impact response is most easily categorized based on the impact velocity (relative approach velocity of two bodies), ranging from elastic response with little change in temperature at low velocities, through plastic deformation and/or fracture at higher velocities, to physical state changes of bodies or a portion of a body at hyper-velocity impacts (> 1 km/sec).

EXPL 414 Explosives Surety, 3 cr, 3 cl hrs

Prerequisite: Upper class standing or consent of instructor

An introduction to explosives and other energetic materials. The basic chemical compositions, properties and environmental effects of commercial, military, and improvised explosives and some pyrotechnics will be compared. The basic physics of shock waves and detonation. Explosive effects, blast detection, tagging and environmental issues. Case studies or recent bombings will be used to describe a variety of terrorist approaches. Safety in handling of explosive materials and classifications for transportation and storage. (Same as ChE 475.)

EXPL 415 Computer Modeling of Detonations, 3 cr, 3 cl hrs

Prerequisite: EXPL 412; or EXPL 311 and MENG 421: or consent of instructor.

Introduction to the numerical/hydrocode modeling of detonation behaviors. Focus on the area of detonation initiation, behavior of heterogeneous explosives, explosive/propellant performances, experiment interpretations, and numerical expressions of explosives relate theories.

EXPL 418 Shock Physics and Structural Response to Blast, 3 cr, 3 cl hrs

Prerequisite: EXPL 412 or consent of instructor

An in-depth study of structural behaviors on blast and vibration. Structure damage prediction/estimation, blasting shockwave mitigation methods/concepts, shockwave propagation/properties on structures, structure failure criteria.

EXPL 419 Experimental and Diagnostic Techniques, 3 cr, 3 cl hrs

Prerequisite: EXPL 412

An introduction to the explosive testing data acquisition systems. Basic concepts of the measurement of detonation product properties and characteristics of detonation process. Analysis of material properties under high pressure shock compression, and data interpretations

EXPL 419L Explosives Testing and Diagnostic Techniques Laboratory, 1cr., 3 cl. hrs

Prerequisite: MENG 545 or EXPL 311 and EXPL 412 or consent of instructor.

Co-requisite: EXPL 419

An introduction to the explosive testing data acquisition systems. Basic concepts of explosives initiation and the measurement/characterization of detonation effects. Experimental analysis of energetic materials and explosives devices utilizing various state-of-art testing equipment. Ultra-high speed camera, VISAR, shock measurement systems, etc. Analysis of material properties under high-pressure shock compression, and data interpretations.

EXPL 489, Special Topics in Explosives Engineering, 3cr., 3 cl. Hrs**EXPL 491 Directed Study, cr to be arranged****Mechanical Engineering Courses:****MENG 110, 110L Introduction to Mechanical Engineering, 2 cr, 1 cl hr, 3 lab hrs**

Corequisites: MATH 103 or higher; MENG 110 and 110 L are co-requisites of each other

A broad overview of mechanical engineering, including an introduction to mechatronics, explosives, thermal and fluid sciences, solid and structural mechanics. Practical hands-on experience using the Mechanical Engineering department's computer-based applications software and lab equipment.

MENG 216, Engineering Fluid Mechanics, 3 cr, 3 cl hrs

Prerequisite: ES 201

Corequisite: MATH 231

Fundamentals of fluid mechanics including fluid statics, velocity of continuous media, continuity, and momentum balance. Introduction of laminar and turbulent flows, similitude, dimensionless analysis, Bernoulli's equation, friction factor, introduction to pump and compressor selection.

MENG 302L, Mechanics of Materials Laboratory, 1 cr, 3 lab hrs

Corequisite: ES 111, ES 302

Experiments in mechanics of materials, testing methods, and measurement techniques.

MENG 304, Advanced Strength of Materials, 3 cr, 3 cl hrs

Prerequisites: ES 302 passed with C or better

Unsymmetrical loading of beams, shear flow and shear center in thin-walled beams, curved beams, thin plates, thick walled cylinders, stress concentrations, thermal stresses, impact loads, and vibration loads. Applying energy methods to various solid mechanics and beam problems.

MENG 305, Engineering Analysis, 3 cr, 3 cl hrs

Prerequisites: ES 111, ES 216/MENG 216, ES 302; MATH 335; or consent of instructor

Solution of linear systems of equations using Gaussian elimination and matrix methods. Scalar and vector fields; gradient; divergence; curl; line, surface and volume integrals; Green's theorem and Stokes' theorem. Solutions to partial differential equations from heat transfer, mechanical vibrations, and fluid mechanics using separation of variables, series and Laplace transforms. (Same as ES 305)

MENG 341, Mechanical Engineering Technical Writing, 3 cr, 3 cl hrs

Prerequisites: ENGL 111 and 112 or the equivalent passed with a grade of C or better.

Corequisites: MENG 381.

This course is designed to offer instruction in theory and practice of effective technical communication, particularly as applied to Mechanical Engineering and the junior/senior design clinic. Students who successfully complete this course should be able to plan, organize, draft, revise, and edit technical communication that is professional in content and appearance and appropriately designed for its intended audience.

MENG 351L, Fluid and Thermal Sciences Laboratory, 1 cr, 3 lab hrs

Prerequisites: ES 216/MENG 216, ES 347, MENG 341
Corequisites: ES 350

Experimental analysis of fluid flow, heat transfer and thermodynamic systems. CFD tools are used for visualization, validation and comparisons with experimental data. A final project in the field of fluid and thermal sciences is required for each laboratory group. Laboratory reports are presented in oral and written formats.

MENG 352L, Instrumentation and Measurement Laboratory, 1 cr, 3 lab hrs

Prerequisites: ES111, MATH 132

An introduction to a variety of programming and simulation environments, such as Matlab, Simulink, and LabView. Conduct experiments using instrumentation in conjunction with data acquisition software and hardware, to develop programs simulating systems and reducing data. The underlined direction of this course will be to simulate, observe, and record natural phenomena in the world of mechanical engineering.

MENG 381, Junior Engineering Design Clinic I, 2 cr, 1 cl hr, 3 lab hrs

Prerequisites: ES 216/MENG 216, ES 302; MATH 335; PHYS 122 & 122L; junior standing

Corequisite: MENG 341

An academic-year-long engineering design project. Organized and directed by a faculty member. Weekly intensive workshops in specialized design topics pertinent to actual design project. Junior-level students are under the direct supervision of the faculty members and the senior-level students assigned to the project.

MENG 382, Junior Engineering Design Clinic II, 2 cr, 1 cl hr, 3 lab hrs

Prerequisite: MENG 341; MENG 381

A continuation of MENG 381 academic-year-long engineering design project.

MENG 405, Dynamic Systems and Controls, 2 cr, 2 cl hrs

Prerequisites: ES 332; MENG 305; MATH 335 or consent of the instructor

Corequisite: MENG 405L or ES 405L

A practical survey course examining the basic components of instrumentation, measurement, and process control systems common to the field of engineering. Sensing and measurement (temperature, pressure, flow rate, level, stress-strain, concentration, etc.), signal generation and data acquisition, control loops and controllers, and process control theory.

MENG 405L, Dynamic Systems and Controls Laboratory, 1 cr, 3 lab hrs

Prerequisite: ES 111; MATH 335

Laboratory exercises involving instrumentation and design of basic control systems.

MENG 421, 421D, Finite Element Analysis and Design, 2 cr, 2 cl hrs

Prerequisites: MENG 304 passed with grade C or better, Math 337 or consent of instructor

Introduction to the theory of finite element analysis for structural and heat transfer analysis. Use of finite element analysis in engineering design.

MENG 421L, Finite Element Analysis and Design Lab, 1 cr, 3 lab hrs

Corequisites: MENG 421

Application of finite element computer codes to solve complex engineering design problems.

MENG 431, 431D, Fluid and Thermal Systems Design I, 3 cr, 3 cl hrs

Prerequisites: MENG 305; ES 350; MATH 335

Advanced dimensional analysis. Design and synthesis of systems based on application of incompressible fluid flow, heat transfer, design optimization theories, and economics. Design problems to include complex pressure conduit and pipe networks, heat exchangers, dynamic and positive displacement pumps, and hydraulic motors.

MENG 441, 441D, Dynamics and Vibrations in Structural Design, 3 cr, 3 cl hrs

Prerequisites: MATH 335 and MENG 305.

ES 332 recommended

Definition of various dynamic loads. Design and synthesis of structural systems and machine members subject to impact and periodic load conditions. Seismic and blast loads on structures. Relevant failure criteria for dynamically loaded systems in structural and mechanism design.

MENG 451, 451D, Design of Machine Elements, 3 cr, 3 cl hr

Prerequisites: ES 303; MENG 304, 305, 381, 382; MATE 202 and 202L

Principles of design and failure analysis of mechanical machine elements such as fasteners, shafts, columns, and gears. Design of mechanical drives such as roller chains, belts, speed reducers, and hydraulic transmissions.

MENG 460, 460D, Introduction to Biomedical Engineering, 3 cr, 3 cl hrs

Prerequisite: Sophomore classification or consent of instructor

An overview of research in biomedical engineering, biomechanics, biocompatibility, tissue engineering, biomedical instrumentation, and moral and ethical issues.

MENG 465, Biorheology, 3cr, 2 cl hrs, 3 lab hrs

Prerequisite: MENG 351L or consent of instructor

Concepts of rheology. Rheology of body fluids. Different rheological models of fluids and applications in diagnosis and treatment of diseases. Laboratory experiments of plasma and blood rheological characterization (viscosity, elasticity, plasticity, etc.).

MENG 481, Senior Engineering Design Clinic I, 3 cr, 1 cl hr, 6 lab hrs

Prerequisite: MENG 382

Corequisite: MENG 451

An academic-year-long engineering design project. Organized and directed by a faculty member. Senior-level students are under the direct supervision of the faculty member. Weekly intensive workshops in specialized design topics pertinent to actual design projects. Topics include costing of capital equipment, cost of materials and labor, design optimization concepts, as well as specialized topics. Formal reports, fabrication drawings, and cost estimates prepared and submitted to faculty and outside industrial reviewers. Formal presentation to reviewing group.

MENG 482, Senior Engineering Design Clinic II, 3 cr, 1 cl hr, 6 lab hrs

Prerequisite: MENG 481

A continuation of MENG 481 academic-year-long engineering design project.

MENG 483, 483D, Mechatronics, 2 cr hr, 2 cl hr

Prerequisites: MENG 352L, MENG 405/405L, and MENG 441; or consent of instructor

Corequisite: MENG 451 or consent of instructor

This course is an in-depth examination of the field of mechatronics, which is a consolidation of computer science (software), electrical engineering (microprocessor control), and mechanical engineering (machine design). Topics covered include: system analysis/ control theory, robotics, dynamic systems and control, elements of mechatronics systems, modeling and simulation of mechatronic systems and computer aided mechatronics.

MENG 483L, Mechatronics Lab, 1 cr hr, 3 cl hr

Corequisite: MENG 483

This is a hands-on lab where the student will design and build a simple mechatronics system. The student will learn the principles of instrumentation and sensors as they relate to the robotic control. The student will also learn the programming methods for the microprocessor controller.

MENG 484L, Design Clinic Lab, 1 cr, 3 lab hrs

Prerequisites: ES or MENG-110, ES or MENG-110L

Corequisites: MENG-381 or consent of the instructor

The Design Clinic Lab Course will introduce students to critical skills important in the engineering design and verification process. Weekly sessions will be conducted in specialized topics pertinent to the design process. Topics include Computer Aided Engineering (CAE), Computer Aided Design (CAD) using Solidworks, mechanical drawing layout, mechanical assemblies, clearances and tolerances, analytical modeling, concepts in machining of components, and the joining of components.

MENG 485, Advanced Design Clinic, 3 cr, 1 cl hrs, 6 lab hrs

Prerequisites: MENG 482

Enables students to enhance their understanding of the engineering design and verification process for mechanical design projects. Weekly seminars in specialized topics pertinent to the design process. Students focus on developing best practices for completing mechanical design projects. These best practices are used to improve the performance of design clinic project teams. Students participate in design project teams, contributing as senior technical members and/or advisers. Students contribute to the formal reports and oral presentations of these teams.

MENG 489, 489D, Special Topics in Biomedical Engineering, 3 cr, 3 cl hrs**MENG 491, 491D, Directed Study, cr to be arranged****Graduate Courses:**

The major content of these courses is directed toward a Master of Science degree in Mechanical Engineering.

MENG 504, 504D, Advanced Mechanics of Materials, 3 cr, 3 cl hrs

Prerequisite: MENG 304 or equivalent or consent of instructor

Development of advanced mechanics of materials principles and techniques for use in engineering design and problem solving. Topics include material yielding, torsion, unsymmetrical bending of beams, shear stresses in thin-walled structures, curved beams, beams on elastic foundations, axisymmetric thin-walled shells and thick-walled cylinders, column stability, stress concentrations, and material failure behavior under steady and cyclic loading.

MENG 515, 515D, Theory of Elasticity, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

An introduction to tensor analysis, analysis of stress, balance laws, infinitesimal and finite theories of motion, strain and rotation tensors, compatibility equations, constitutive equations, materials symmetry, uniqueness of the solution, solution of two-dimensional elasticity problems. Airy stress function, application of complex variable technique in elasticity, three-dimensional elasticity problems, energy methods, bending theory of plates. (Same as ME 515)

MENG 516, 516D, Plates and Shells, 3 cr, 3 cl hrs

Prerequisites: MENG 305, MENG 451 or approval of the instructor.

Behavior, analysis and design of discrete and continuous plates and shells, membrane and bending behavior, numerical methods of solution.

MENG 517, 517D /ME 517, Advanced Finite Element Method, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

An introduction to the numerical analysis calculus of variation, weak form of a differential equation, weighted residual techniques, solution of one-dimensional problems by the finite element method, bending problems, Lagrange and Hermite interpolation functions, isoparametric elements, numerical integration, two-dimensional problems, solution of Poisson and Laplace equations, triangular and quadrilateral elements, elasticity problems, theorem of minimum potential energy stiffness matrix, examples. (Same as ME 517)

MENG 519, 519D, Adaptive Structures, 3 cr, 3 cl hrs

Prerequisites: MENG 305, Pre/Corequisite MENG 589 or approval of the instructor

Adaptive structures with embedded intelligent sensors and actuators, self-monitoring and self healing characteristics, biological system/ structures.

MENG 520, 520D, Fracture Mechanics, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

An introduction to the theory of elasticity, singular stress fields, Westergaard method, complex variable technique, stress intensity factor, fracture energy, numerical and experimental methods in determination of stress intensity factor, fracture toughness, J-integral Elasto-plastic fracture. (Same as ME 520)

MENG 521, Elastic Stability, 3 cr, 3 cl hrs

Prerequisite: MENG 304 or consent of the instructor

Classical theory of elastic stability for beams, plates, and shell structures. Geometric non-linear equations for thin-walled structures. Linear, linearized, and non-linear solutions of problems. Approximate analytic methods and numerical methods for problem solving.

MENG 522, Mechanics of Inelastic Continuum, 3 cr, 3 cl hrs

Prerequisites: MENG 515, MENG 524 or approval of the instructor

Modeling systems that yield inelastic equations, coupled with methods for their solutions and analysis. Development of insight into the fundamental behavior of inelastic systems.

MENG 523, Engineering Mechanics of Cellular Structures, 3 cr, 3 cl hrs

Prerequisites: MENG 305, Pre/Corequisite MENG 589 or approval of the instructor

Cellular structures with combinations of mechanical, energy-absorption, thermal and acoustic/vibration characteristics and their implementation in diverse applications.

MENG 524, 524D, Continuum Mechanics, 3 cr, 3 cl hrs

Prerequisites: MENG 515, Pre/Corequisite MENG 517 or approval of the instructor

Matrix, indicial and direct notation, tensor calculus, deformation analysis; general principles of stress, curvilinear coordinates.

MENG 531, Mechanics of Viscous Fluids, 3cr, 3 cl hrs

Prerequisite: MENG 431 or consent of the instructor

Fundamental laws of motion for a viscous fluid. Navier-Stokes equation. Laminar fluid flow, turbulent boundary layer topics. Compressible and incompressible flow problems.

MENG 541, 541D, Vibrations in an Elastic Continuum, 3 cr, 3 cl hrs

Prerequisites: ES 302, 303; MENG 441; or consent of instructor

Analysis of single and multi degree-of-freedom systems for time dependent loads, including periodic and impact loads. Thin-walled structures—beams, plates, and shells. Dynamic stability of thin-walled structures.

MENG 544, 544D, Modern Control Theory, 3 cr, 3 cl hrs

Prerequisites: MENG 405 or consent of instructor

Designing and analyzing modern control systems that can be devised from dealing exclusively in the time domain. Methods of expanding control concepts from simple single-input single-output processes to full multi-input multi-output, continuous and discrete, linear and nonlinear systems will be explored. Students will submit a semester-long research paper.

MENG 545, 545D, Introduction to Explosives Engineering, 3 cr, 3 cl hrs

Prerequisites: ES 216, ES 302 and ES 347; or consent of instructor

Introduction to the broad field of explosives science and technology. Basic organic chemistry, decomposition reactions, properties of explosives, thermodynamics of explosives, shock wave theory, detonation theory, initiators, Gurney equations, blast effects and demolition. Students will submit a semester-long research report.

MENG 546, 546D, Detonation Theory, 3 cr, 3 cl hrs

Prerequisites: MENG 549 or consent of instructor. MENG 556 recommended.

Development of classical detonation model for full order detonation of secondary explosives. Ideal versus non-ideal detonation. Burn-rate models for pyrotechnics. The concept of deflagration to detonation transition. (Same as ME 546)

MENG 547, 547D, Theory and Application of Pyrotechnics, 3 cr, 3 cl hrs

Prerequisites: MENG 545 or consent of instructor

Fundamentals of basic concepts of pyrotechnic. Thermo-mechanical/chemical aspects of pyrotechnics, formulation and mixing of pyrotechnic mixtures, application of pyrotechnic including illumination, tracers, incendiaries, delays, etc.

MENG 548, Manipulator Based Robotics, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisite: MENG 405 or equivalent or consent of instructor

Fundamentals of the multi-disciplinary field of robotics. Emphasis is placed on understanding how to model and control robotic manipulators while providing an appreciation of the importance of sensing to robotic applications. Topics include: forward, inverse, and motion kinematics; dynamic modeling; position, velocity, and force control. Shares lecture/lab with EE 448, but is graded separately, and additional graduate-level work is required. (Same as EE 548)

MENG 549, 549D, Wave Propagation, 3 cr, 3 cl hrs

Prerequisites: MENG 545 and MATH 335; or consent of instructor

An in-depth study of the propagation of waves in various media. The derivation and application of the Rankine-Hugoniot jump equations. The concept of the rarefaction wave and various wave interactions. Derivation and application of the Mie-Grüneisen equation of state. The differential form of the conservation equations, as well as some numerical solutions for simple cases. Shares lecture with EXPL 412, with additional expectations for graduate credit. (Same as ME 549)

MENG 550, 550D, Advanced Explosives Engineering, 3 cr, 3cl hrs

Prerequisites: MENG 549 or consent of instructor

The detonation of non-ideal explosives, equation of state for porous media, shaped charge effect and explosively formed projectiles. Shock compaction of powders, explosive welding and experimental methods used in the evaluation of explosives and their applications. The dynamic fracture of ductile and brittle materials. (Same as ME 550)

MENG 551, 551D, Optimal Control Systems, 3 cr, 3 cl hrs

Prerequisites: ES 332, MATH 254 or equivalent, MATH 335, MENG 405

Formulation of stochastic dynamic systems models, combined with optimal full-state and reduced-state estimators are introduced. Various cost functionals are defined and used to design real-time control algorithms that produce specific desired system responses. Mathematical measures of control robustness are defined which allow the student to gain an appreciation for predicting and measuring system stability margins under sub-optimal conditions.

MENG 552, 552D, Explosives Technology and Applications, 3 cr, 3 cl hrs

Prerequisites: MENG 545 or consent of instructor

Focus on the application of explosives mechanics. Fundamentals of explosive welding/cutting, shaped charges, explosive-drives flux compression generators, spallations, explosives initiation methods, explosives applied testing methods, etc. Students will submit a semester-long research report.

MENG 553, 553D, Computer Modeling of Detonations, 3 cr, 3 cl hrs

Prerequisites: MENG 519 or consent of instructor. MENG 517 is recommended.

Introduction to hydrodynamic modeling applied to explosives. Numerical methods for modeling shock physics, detonation, and material response. Finite difference, finite element and smoothed particle hydrodynamic methods, equation of state and strength models, and numerical fracture and fragmentation. (Same as ME 553)

MENG 554, Embedded Control Systems, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: EE 308 or EE 443 or MENG 405 or equivalent or consent of instructor

Micro-controller or microcomputer based embedded control systems. A comparative survey of currently available embedded computers/controllers including SBC's, PIC's, basic-stamps, and single-chip computer solutions. Real time operating systems including real-time LINUX, and hard real-time process requirements. Projects will include the implementation of an embedded real-time control solution. (Same as EE 554)

MENG 555, Shock Physics and Structural Response to Blast, 3 cr, 3 cl hrs

Prerequisites: MENG 549 or consent of instructor

An in-depth study of structural behavior during blast and vibration. Structure damage prediction/estimation, blasting shockwave mitigation methods/concepts, shockwave propagation/properties on structures, structure failure criteria. Students will submit a semester-long research report.

MENG 556, 556D Compressible Fluid Flow, 3 cr, 3 cl hrs

Prerequisites: ES 216/MENG 216, ES 347, ES 350, MENG 431, MATH 335

Explanation of the physical phenomena encountered in compressible flow by providing practical applications and examples. Provide the knowledge and understanding of the basic fundamentals of compressible flow and gas dynamics.

MENG 557, Multiphase Flow, 3 cr, 3 cl hrs

Prerequisites: MENG 431 or equivalent or consent of the instructor

Selected topics in multiphase flows with emphasis on engineering applications. Topics include basic two-phase flow equations, pressure drop in two-phase flow, gas-liquid, gas-solid and liquid-solid two-phase flows.

MENG 558, 558D, Non-Newtonian Fluid Mechanics, 3 cr, 3 cl hrs

Prerequisite: consent of the instructor

This course offers the specific techniques and understanding necessary for being able to compute and understand issues associated with non-Newtonian fluid dynamics. Issues of rheology and analytic techniques are covered.

MENG 559, Theory and Design of Internal Combustion Engines, 3 cr, 3 cl hrs

Prerequisites: ES 347, ES 350, MENG 304, MENG 421, or consent of the instructor

Thermodynamic analysis and performance characteristics of spark ignition and compression ignition engines. Effects of thermodynamics, heat transfer and combustion on engine power, efficiency and emissions. Design of internal combustion engines; stress analysis, kinematics and dynamics of the crank mechanism, design of piston, connecting rod and crankshaft.

MENG 560, 560D, Principles of Combustion, 3 cr, 3 cl hrs

Prerequisites: ES 347 or consent of the instructor

Covers the fundamentals of combustion. Topics include chemical reactions, calculation of adiabatic flame temperature, chemical kinetics and flammability limit, characteristics of premixed, diffusion, laminar and turbulent flames.

MENG 567, 567D, Smart Engineering Systems, 3 cr, 3 cl hrs

Prerequisites: MATH 254, 382; CSE 344; or equivalent; or consent of instructor

Artificial neural networks, with emphasis on multiplayer feedback networks, self-organizing networks, and Hopfield-style networks. Learning algorithms. Introduction to fuzzy systems and evolutionary computing. Engineering applications of soft computing.

MENG 568, Smart Engineering Systems II, 3 cr, 3 cl hrs

Prerequisites: MATH 254, 382; CSE 344; or equivalent; or consent of instructor

Overview of the major paradigms of soft computing: neural networks, fuzzy systems, and evolutionary computing. In-depth coverage of selected topics in each area as relevant to intelligent systems. Recent advances in the field, and case studies of intelligent systems. Coursework includes a large-scale project.

MENG 570, 570D, Advanced Mechatronics, 3 cr, 3 cl hrs

Prerequisite: MENG 405 or EE 443 or equivalent or consent of instructor

The theory, design, manufacture and use of instrumentation and control in the various sciences. The use of electrical and electronic instruments and equipment to measure, monitor and/or record physical phenomena. Measurements of force, mass dimension, strain; displacement, velocity, and acceleration; tensile, impact and comprehensive strength; temperature and thermal properties; time and frequency; thrust and torque; pressure vacuum and flow; electrical quantities; photo-optics and radiation.

MENG 571, Haptic Systems, Teleoperation, & Virtual Reality, 3 cr, 3 cl hrs

Prerequisite: MENG 405 or EE 443 or equivalent or consent of instructor

Haptic and virtual-reality interfaces are designed with the sensing, control, and actuation capabilities of both humans and robots in mind. This course provides a practical introduction to select aspects of these capabilities. Mathematical formulations fundamental to the course will be derived. Students' ability to comprehend and synthesize the often dense and technical content of research papers will be improved through frequent reading and discussion assignments. Students will design computer algorithms throughout the semester that will culminate in a final programming project.

MENG 572, 572D, Sensor Technology, 3 cr, 3 cl hrs

Prerequisites: ES 332 and MENG 405, or EE 443 or equivalent, or consent of instructor

The operating principles and properties of sensors/transducers for the measurement of physical quantities in the mechanical domain, as well as the associated interface circuits. Focus is on commercially available sensors, but where appropriate, recent trends toward miniaturization, integration, and higher quality performance will be addressed.

MENG 574, Electrical Measurements of Non-Electrical Quantities, 3 cr, 3 cl hrs

Prerequisites: ES 332 and MENG 405, or EE 443 or equivalent, or consent of instructor

This course is particularly reliant on advances in scientific knowledge. Establishment of units and scales of measurement, their development, realization, maintenance and dissemination, as well as the performance of traceable measurements. Hence, this course serves a key factor of modern manufacture through automation, which both enhances productivity and ensures consistent quality. The demand for improved and assured quality means ever better instrumentation. Focus on the course will be on measurement science, design principles for instrument systems, electrical measurements of thermal quantities, electrical measurements of mechanical quantities, electrical measurements of optical quantities, and electrical measurements of chemical quantities.

MENG 575, 575D, Advanced Engineering Mathematics, 3 cr, 3 cl hrs

Prerequisites: MENG 305 or consent of the instructor

A comprehensive study of applied mathematics. Vector analysis, tensors and Eigenvalue problems. Analytical solutions to linear ordinary and partial differential equations. Separation of variables, boundary value problems, and Laplace and Fourier transforms. Numerical analysis of non-linear ordinary and partial differential equations with emphasis on engineering applications. Complex Analysis; complex numbers, Cauchy-Riemann equations and conformal mapping.

MENG 576, 576D, Biomedical Mechatronics, 3 cr, 3 cl hrs

Prerequisites: MENG 405 or EE 443 or ES 332 or equivalent or consent of instructor

This course will give students direct experience with computational tools used to create simulations of human movement. Lectures and labs cover animation of movement; kinematic models of joints; forward dynamic simulation; computational models of muscles, tendons, and ligaments; creation of models from medical images; control of dynamic simulations; collision detection and contact models. The course is intended as an introduction to medical device design for graduate engineering students because the class will have a significant design and prototyping emphasis.

MENG 577, 577D, Advanced Fluid Mechanics, 3 cr, 3 cl hrs

Prerequisites: MENG 431 or equivalent

Corequisite: MENG 575

Fundamental concepts and analysis of Fluid Mechanics. Derivation of the partial differential equations governing the conservation of mass, momentum and energy. Introduction to potential flows. Exact solutions of the Navier-Stokes equations. Laminar and turbulent boundary layers. Compressible and incompressible flow problems.

MENG 578, 578D, Advanced Thermodynamics, 3 cr, 3 cl hrs

Prerequisites: ES 347 or consent of the instructor

The first and second laws of thermodynamics. Clapeyron relation, availability concepts and analysis, equations of state, non-reacting mixtures and thermodynamics of chemical reactions.

MENG 579, 579D, Advanced Heat Transfer, 3 cr, 3 cl hrs

Prerequisites: ES 350 or consent of the instructor

Covers analytical and numerical techniques in conduction, convection, radiation with emphasis on combined heat transfer.

MENG 580, 580D, Computational Fluid Dynamics and Reactive Flow, 3 cr, 3 cl hrs

Prerequisites: MENG 560, MENG 577 or consent of the instructor

Introduction to Computational Fluid Dynamics and application of CFD tools to thermal and fluid flow problems. Coupling of fluid flow with combustion chemistry. Discussion of combustion modeling, importance of the mixing intensity, heterogeneous and homogeneous chemical reactions, and application of computer analysis to chemically reacting flow problems.

MENG 581, Directed Study, cr to be arranged**MENG 582, 582D, Nondestructive Evaluation and Structural Health Monitoring, 3 cr, 3 cl hrs**

Prerequisites: MENG 304, MENG 305, MATH 335 or consent of instructor.

This multi-disciplinary course introduces key physical concepts in elasticity, material science, acoustics, optics, and electromagnetics applied to system condition monitoring, material characterization, structural damage detection and failure prevention. A broad spectrum of nondestructive evaluation (NDE) methods and emerging structural health monitoring (SHM) technologies is discussed including the ultrasonic inspection, vibration monitoring, acoustic emission, radiography, eddy currents, electrical and magnetic testing. Examples of practical NDE/SHM applications in scientific research and industrial practice are presented.

MENG 583, 583D, Engineering Mechanics of Composite Structures, 3 cr, 3 cl hrs

Prerequisites: MENG 305, Pre/Corequisite MENG 523 or consent of the instructor

Composite structures, Macro-mechanics to Structural design and development. Development of analytical procedures for determining material properties, effective experimental methods and prediction of structural behavior.

MENG 585, 585D, Graduate Seminar, 1 cr**MENG 586, 586D, Advanced Topics in Engineering Science, 2 - 3 cr each semester**

Prerequisites: MENG 549 or consent of the instructor

MENG 589, Impact Dynamics, 3 cr, 3 cl hrs

Prerequisites: ES 303, ES 305, MENG 305 or equivalent

A specialized but very important branch of engineering mechanics deals with the collision of multiple bodies throughout a broad range of relative velocities. The physical phenomenon during impact and subsequent response of each of the bodies is dependent on the mechanical material properties of each, the impact velocities, and the relative size and orientation of each of the bodies. Impact response is most easily categorized based on the impact velocity (relative approach velocity of two bodies), ranging from elastic response with little change in temperature at low velocities, through plastic deformation and/or fracture at higher velocities, to physical state changes of bodies or a portion of a body at hyper-velocity impacts (> 1 km/sec).

MENG 590, Independent Study, cr to be arranged**MENG 591, Thesis (master's degree), cr to be arranged****Faculty Teaching & Research Interests**

Abernathy – Energetic Materials Testing and Computational Analysis

Bakhtiyarov – Non-Newtonian Fluid Mechanics, Heat and Mass Transfer, Rheology, Multiphase Flows, Instrumentation, Fluidized Beds, Porous Medium Flows, Nanotechnology, Self-Healing Materials, Tribology, Turbulence

Cooper - Explosives Technology, Explosives Engineering

Dinwiddie - Dynamic Antenna Modeling

Fakhimi - Geomechanics, Numerical Modeling

Ford – Written and Oral Communication, Teamwork, Communication Pedagogy, Leadership

Field – Structural Dynamics, Random Vibration, Applied Probability, Computational Modeling, Model Validation, and Robust Control

Fortner – Energetic Materials: Initiation, Applications, and Systems

Ghosh – Macro Behavior of Composites, Biomechanics, Finite Element Analysis, Experimental Mechanics and Instrumentation, Structural Health Monitoring and Restoration, Construction Materials and Project Management

Grow – Robotics, Biomedical & Surgical Devices, Haptics, Dynamic Modeling

Hargather – Shock and Gas Dynamics, Experimental Thermal-Fluid Dynamics, High-Speed Gas Dynamics, Thermal Convection Problems

Kennedy - Basic Science and Applications of Explosives, Microdetonics and Initiation of Detonation in Explosives

Kimberley – Solid Mechanics, Impact Studies, Dynamic Behavior of Materials

Lim-Energetic Materials, Explosives Technology, Linear and Conical Shaped Charges

Marcy – General Aviation, Conceptual Design

Meason – Explosives Technology

Miller, A. – Finite Element Analysis, Explosive Synthesis of Materials, High-Temperature Systems

Miller, A.K. – System Dynamics, System Modeling and Simulation, Actuators and Actuator Controls

Ostergren – Mechanics of Materials, Structural Analysis, Machine Design, Propulsion and Power Systems

Rivera – Energetic Materials, Explosives Technology
Romero – Energetic Materials, Shock Phenomena, High Energy Physics

Ruff – Mechanics of Materials, Instrumentation

Ryu – Mechanics of Materials, Smart Materials and Structures, Continuum Mechanics, Sustainable Infrastructures, Structural Health Monitoring, Advanced Sensing Technologies, Autonomous Composites, Multifunctional Materials, Nanomaterials and Nanocomposites, Optics and Optoelectronics

Stofleth – Instrumentation and Measurements, Explosives Technology

Wei – Thermal-Fluid Science, Wall-Bounded Flow, Flow Instabilities, Enhancing or Reducing Heat Transfer Coefficients, Turbulent Mixing, and Fluid Drag.

Westpfahl - Dynamics of Spiral and Dwarf Galaxies

Yilmaz - Computational Fluid Dynamics, Combustion and Chemical Kinetics, Rocket Propellants, Internal Combustion Engines, Alternative Fuels, Renewable Energy

Zagrai---Structural Dynamics and Acoustics, Intelligent Systems and Structures, Sensor Networks, Structural Health Monitoring and Nondestructive Evaluation.

Mineral Engineering

Professors Chávez, Fakhimi, N. Mojtabai (Chair of the Department)

Associate Professor Razavi

Adjunct Faculty Bakhtar, Gundiler, Kuhn, McLemore, Preece, Wimberly

Emeritus Professor Oravec, Aimone-Martin

Degrees Offered: B.S. in Mineral Engineering; B.S. in Mineral Engineering with Emphasis in Explosives Engineering; M.S. in Mineral Engineering

Department Mission Statement

- Provide the students with an education in the fundamentals of engineering that will allow immediate entry into industry, government, research or academia and provide a solid theoretical and applied foundation for future professional development and growth.
- Maintain high level of commitment and excellence in teaching and research, provide the time and effort to understand the individual students particular learning abilities and needs, give guidance and provide the environment to achieve those abilities.
- Prepare students for the opportunities and challenges of a diversified professional career in the rapidly changing mineral engineering related disciplines through exposure to various aspect of applied technology.

Program Educational Objectives

Program graduates will:

- 1) Develop creativity in thinking and skills in problem solving to enhance their employer's ability to be competitive within industry, as they advance in their professional career.
- 2) Develop leadership communication skills within the framework of a team while demonstration the ability to work independently.
- 3) Maintain a strong sense of professional and ethical responsibility with a strong corresponding sense of social awareness.
- 4) Advance in engineering or management status and demonstrate measurable progress in achieving personal and professional goals after graduation.

Mineral engineering is concerned with the exploration for and development of minerals and earth materials in the most efficient manner while protecting the environment. The undergraduate program is oriented toward developing the student's understanding of, and skill in, engineering design. Proficiency in project management and leadership are encouraged through coursework and projects that emphasize professional-quality written and oral communication skills. The objective of the program is to provide the student with an education in the fundamentals of engineering that will allow immediate entry into industry or research work while providing a good opportunity for continued professional growth. Emphasis is placed on developing a responsible professional with a sense of social awareness.

The curriculum includes basic engineering principles that provide the foundation for applied engineering design concepts. The program provides a concentrated study in mechanics, mineral evaluation and economics, ground and environmental control, environmental issues, and project management. Engineering design is introduced in courses covering surface and underground mining, ventilation, mineral processing, equipment selection, drilling and blasting, soil and rock mechanics, hydraulic structures, and geomechanics. Instruction in the environmental aspects of minerals development and production include mine permitting and reclamation, extending to the legal issues and concerns in natural resources development.

A large-scale design project is undertaken in the senior year. This project integrates engineering principles and design in one of three areas: economic evaluation and exploration for mineral properties; design and planning of a mining project; or the planning and implementation of geotechnical construction projects, such as landfills, tailings impoundments, earth dams, and structures.

The department has modern well-equipped laboratories for instruction and research in soil and rock mechanics, ventilation, blast vibrations, mineral evaluation, and computer applications. The department also maintains its own experimental underground mining facility to allow students valuable hands-on experience in solving mineral engineering problems. Students are provided the opportunity to work on a wide range of applied research projects within both the department and the Institute. Students are encouraged to obtain summer jobs available in mines across the Southwest, providing excellent industrial experience.

Undergraduate Program

Bachelor of Science in Mineral Engineering

Minimum Credit Hours Required—130

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- MATH 231 (4), 335 (3)
- ES 201 (3), 216 (3), 302 (3), ES 303 or 347
- EARTH 101 & 103L, 200 (4)
- ME 101 (1), 220 (3), 320 (2), 340 (3), 360 (3), 380 (6), 410 (3), 413 (3), 419 (2), 420 (3), 422 (3), 435 (3), 437 (3), 440 (3), 462 (3), 470 (1), 471 (2)
- Technical Elective (3)
- Electives to complete 130 credit hours

Bachelor of Science in Mineral Engineering with Emphasis in Explosives Engineering

Minimum credit hours required—138

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- MATH 231 (4), 335 (3)
- ES 201 (3), 216 (3), 302 (3), ES 332, ES 303 or 347 (3)
- EARTH 101 & 103L (4), 200 (4)
- ME 101 (1), 220 (3), 320 (2), 340 (3), 360 (3), 380 (6), 410 (3), 419 (2), 420 (3), ME 422 (3), ME 435 (3), ME 437 (3), 440 (3), 462 (3), 470 (1), 471 (2)
- Technical Elective (3),
- Three approved courses from any of the explosive engineering courses offered on campus.

Students are strongly encouraged to do their senior design project in the area of Explosive Engineering or related projects

Minor in Mineral Engineering

Minimum credit hours required—18

Chosen from the following courses:

ME 220 (3), ME 320 (2), ME 340 (3), ME 360 (3), ME 380 (6), ME 410 (3), ME 413 (3), ME 420 (3), ME 422 (3), ME 435 (3), ME 437 (3), ME 440 (3), ME 462 (3)

Sample Curriculum for the Bachelor of Science in Mineral Engineering

Semester 1

- 1 ME 101 (intro to mineral engineering)
- 4 EARTH 101 & 103L (principals)
- 4 MATH 131 (calculus I)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 16 Total credit hours

Semester 2

- 3 ENGL 112 (college English)
- 4 MATH 132 (calculus II)
- 4 CHEM 122 & 122L (general)
- 3 Social Science/Humanities
- 3 Social Science/Humanities
- 17 Total credit hours

Semester 3

- 5 PHYS 121 & 121L (general physics)
- 4 MATH 231 (calculus III)
- 3 ES 201 (statics)
- 3 ME 220 & 220L (surveying)
- 3 Social Science/Humanities
- 18 Total credit hours

Semester 4

- 5 PHYS 122 & 122L (general physics)
- 3 ES 216 (fluid mechanics)
- 3 ES 302 (strength of materials)
- 4 EARTH 200 (mineralogy)
- 2 ME 320 (economic analysis)
- 17 Total credit hours

Semester 5

- 3 ME 360 (exploration and field mapping)
- 3 ME 340 (geostatistics and mineral evaluation)
- 3 ENGL 341 (technical writing)
- 3 ME 420 & lab (soil mechanics)
- 3 Humanities/Social Science
- 15 Total credit hours

Semester 6

- 6 ME 380 & 380L (mine systems)
- 3 ME 413 (foundation engineering)
- 3 ME 422 & 422L (rock mechanics)
- 3 Social Science/Humanities
- 15 Total credit hours

Semester 7

- 1 ME 470 (senior design I)
- 3 ME 435 (rock slope stability)
- 3 MATH 335 (applied analysis)
- 3 ES 347 (thermodynamics) or ES 303 (dynamics)
- 3 ME 440 (mine ventilation)
- 3 ME 410 & 410L (environmental issues)
- 16 Total credit hours

Semester 8

- 2 ME 471 (senior design II)
- 2 ME 419 (mineral and natural resources law)
- 3 ME 462 (mineral deposits)
- 3 ME 437 (tunneling & underground excavations)
- 3 Technical Elective
- 3 Humanities/Social Science
- 16 Total credit hours

Graduate Program

Master of Science in Mineral Engineering

Admission to the Master of Science in Mineral Engineering program requires competence in mathematics, chemistry, physics, and engineering science comparable to the bachelor of science degree in mineral engineering. Applicants without an engineering degree may apply for the graduate program in Mineral Engineering. However, the student will be required to take ES 201, ES 302, and ME 420. Any other deficiencies may have to be covered as required the advisory committee.

The student's course of study must be approved by the student's advisory committee and fulfill the general requirements for the master's degree.

Of the 30 hours required for the M.S. degree, a minimum of 12 credit hours must be in approved Mineral Engineering courses. All graduate students must complete at least one credit of ME 572 (graduate seminar). Under special consideration, a student may petition the advisory committee with approval of the Department Chair to pursue a Master of Science degree with Independent Study (three hours of ME 590). A formal paper will be submitted with an oral presentation to the advisory committee.

The student may select one area of specialization as outlined below; within each specialization, recommended courses are provided.

Specialization in Mineral Exploration

At least 12 credits selected from ME 511, ME 521, ME 522, ME 523, ME 551, ME 562, ME 563. Other courses can be substituted with the approval of the research advisor and committee.

Specialization in Geotechnical Engineering

At least 12 credits selected from ME 506, ME 508, ME 515, ME 517, ME 520, ME 525, ME 531, ME 534, ME 535, ME 537, ME 540, ME 541, ME 561. Other courses can be substituted with the approval of the research advisor and committee.

Specialization in Explosive Engineering

At least 12 credits selected from ME 515, ME 517, ME 520, ME 534, ME 545, ME 546, ME 548, ME 549, ME 550 or MENG 550, ME 552, ME 553 or MENG 570. Other courses can be substituted with the approval of the research committee and the department.

Mineral Engineering Courses:

ME 101, Introduction to Mineral Engineering, 1 cr, 1 cl hr

The fundamentals of geology and mineral resource exploration and development applied to engineering. The role of the mineral engineer in mining, exploration, and geotechnical engineering. Field trips to mining and construction operations as well as guest speakers from industry, government, and research.

ME 215, Health and Safety, 2 cr, 2 cl hrs

Offered on demand

The roles of health and safety in the construction, operation, and maintenance of extractive mineral facilities. Federal and state health and safety codes. Laboratory and field work.

ME 220, Surveying and Map Preparation, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: MATH 103, 104

Surveying instruments and measurement techniques. Data acquisition by means of advanced surveying methods for map production. Layout design and measurements. Correlations of surface and underground surveys.

ME 320, Economic Analysis, 2 cr, 2 cl hrs

Corequisite: MATH 131

Economic principles applied to decision-making problems in mineral engineering. Compound interest, depreciation, present worth and rate of return pertinent to project evaluation.

ME 340, Geostatistics and Mineral Evaluation, 3 cr, 2 cl hr, 2 lab hrs

Prerequisites: ME 320

Introduction to statistics. Obtaining, evaluating, and presenting mineral resource information. Ore reserves estimation using geometric weighting techniques and geostatistical methods. The use of computers is emphasized.

ME 360, Exploration and Field Mapping, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: EARTH 200; ME 220

Corequisite: ENGL 341

The acquisition and presentation of field geological data applied to engineering site characterization and mineral exploration. Data presentation. Elements of exploration techniques including field applied mineralogy, geophysics, structural geology, geochemistry, drilling and sampling, and mapping. Laboratory reports and oral presentations.

ME 380, Mine Systems, 6 cr, 4 cl hrs, 6 lab hrs

Prerequisite: ME 340, ME 320, or ES 316

Surface and underground mining methods and design; drilling and blasting design; materials handling and equipment selection. Concepts of mine plant design. Emphasis on computer applications.

ME 410, Environmental Issues, 3 cr, 3 cl hrs

Prerequisites: ME 380

Corerequisite: ME 413

Mine waste characteristics; regulations affecting mine operations; site selection, design and stability analysis of tailings impoundments. Water quality issues and control in mining. Mine waste management. Mine permitting requirements and reclamation. Design projects.

ME 413, Foundation Engineering, 3 cr, 3 cl hrs

Prerequisite: ME 420

Principles of soil mechanics and foundation engineering. Immediate and time dependent settlements, service loads, lateral loads, loading, approximate analysis methods, performance requirements, shallow foundations, lateral earth pressure, design of retaining walls, deep foundations, special footings, slope stability, and computer modeling of foundations. (Same as CE 413).

ME 419, Legal Aspects of Mineral Engineering, 2 cr, 2 cl hr

A comprehensive study of laws pertaining to the exploration, planning, and development for resource extraction including minerals and water. Mineral and water rights issues will be presented and debated. A case study paper will be presented.

ME 420, Soil Mechanics, 3 cr, 2 cl hrs, 3 lab hrs

Corequisites: ES 302

Phase relationships, soil classification, clay mineralogy, compaction, flow of water in soils, effective stress, Mohr circle, stress-strain relationships and failure criteria, Mohr-Coulomb failure criterion, shear strength, consolidation, and consolidation settlement.

ME 421, Applied Economic Geology, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: EARTH 200

Offered on demand

Lithologic and lithochemical characterization of metalliferous ore deposits through the use of ore and alteration sample suites collected from various classes of deposits. Identification of hand specimen mineralogy; thin section and polished section analyses to establish paragenesis of both ore and gangue mineralization. Theoretical considerations ascertained by use of appropriate phase diagrams. Interpretation of wallrock alteration and characteristics of mineral paragenesis for major ore deposit types. Design and implementation of mineral exploration using field and laboratory observations.

ME 422, Rock Mechanics, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: ME 420

Mechanical properties of intact rock and rock masses, classification of rock masses for engineering purposes, rock failure criteria, in situ stress measurement techniques, rock deformability. Labs consists of sample preparation, point load test, Brazilian test, Uniaxial test, and Triaxial test.

ME 427, Site Investigation, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: ME 420

Offered on demand

Design of engineering site investigation for project planning and construction; acquisition, presentation, and interpretation of geologic field data for engineering design. Design concepts for rock and soft ground tunneling, rock slopes, tailings dams, landslides, ground subsidence, collapsible and swelling soils. Computer-aided data reduction and design.

ME 434, Drilling and Blasting Engineering, 3 cr, 3 cl hrs

Prerequisite: ES 302

Offered on demand

Introductory course in the application of explosives to rock fragmentation; theory of detonation and mechanisms of rock failure, dynamics, and propagation. The effects of rock properties on breakage. Blasting systems and production blasting techniques used in both surface and underground designs; environmental considerations and regulations. Principles of blasthole drilling and drill performance. Drilling and blasting economics.

ME 435, Rock Slope Engineering, 3 cr, 3 cl hrs

Prerequisite: ME 422

Field exploration and presentation of geologic data pertaining to rock slope engineering. Shear strength of rock discontinuities. Structural analyses and application of stereonet and stereographic projection. Basic mechanics and modes of slope failure. Plane, wedge, and toppling failure analyses. Effect of groundwater. Improvement of slope stability by drainage and support. Monitoring. Computer applications. Shares lecture with ME 535, with additional expectations for graduate credit.

ME 437, Tunneling and Underground Excavation, 3 cr, 3 cl hrs

Prerequisite: ME 422

Field exploration and presentation of geologic data pertaining to underground excavations in rock. Rock mass classification systems. Empirical design and support selections, structural analysis and block stability. Application of stereonets and stereographic projection. Stress and rock mass strength, elastic and elasto-plastic analysis. Applications of numerical modeling. Review of machine excavation methods. Shares lecture with ME 537, with additional expectations for graduate credit.

ME 440, Mine Ventilation, 3 cr, 3 cl hrs

Prerequisite: ME 380; ES 216

Control of underground environmental problems; dusts, gases, temperature, and humidity. Analysis of natural and mechanical ventilation systems and equipment. Measurement techniques

ME 462, Mineral Deposits, 3 cr, 2 cl hrs, 2 lab hrs

Prerequisite: EARTH 203

Ore formation processes and ore mineralogy; geologic and geochemical characterization of ore deposits using hand specimen, petrographic, and field mapping techniques. Visits to prospects and operating mines to observe variations in ore deposit characteristics to document geologic and geochemical parameters used to describe ore-forming systems. (Same as EARTH 462)

ME 470, Senior Design I, 1 cr, 1 cl hr

Prerequisites: ME 380

Initiation of senior design project including written and oral project proposal; estimation of project design requirements and costing. Preliminary data acquisition and evaluation. Design topics are selected from mineral exploration, mine or geotechnical engineering.

ME 471, Senior Design II, 2 cr, 2 cl hrs

Prerequisite: ME 470 passed with a grade of "C" or better.

Continuation of design projects initiated in ME 470; implementation and evaluation of design details including cost analysis. Preparation of final project report with written and oral professional-style presentations.

ME 491, Directed Study, 1–4 cr as arranged

Special projects or topics in mining or geological engineering.

ME 500, Directed Research, cr to be arranged

This course may not be used to fulfill graduate degree requirements. Research under the guidance of a faculty member.

ME 506, Soil Mechanics, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: Consent of instructor

Phase relationships, soil classification, clay mineralogy, compaction, flow of water in soils, effective stress, Mohr circle, stress-strain relationships and failure criteria, Mohr-Coulomb failure criterion, shear strength, consolidation, and consolidation settlement.

ME 508, Rock Mechanics, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: consent of instructor

Mechanical properties of intact rock and rock masses, classification of rock masses for engineering purposes, rock failure criteria, in situ stress measurement techniques, rock deformability. Labs consists of sample preparation, point load test, Brazilian test, Uniaxial test, and Triaxial test.

ME 511, Mineral Economics, 3 cr, 3 cl hrs

Prerequisite: ES 316 recommended, or consent of instructor

Domestic and international mineral statistics, marketing, trade, conservation, and taxation. Energy economics. Labor economics. Economic calculations for feasibility studies on mineral properties. Participants prepare and present professional-style reports on international mineral development.

ME 515, Theory of Elasticity, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

An introduction to tensor analysis, analysis of stress, balance laws, infinitesimal and finite theories of motion, strain and rotation tensors, compatibility equations, constitutive equations, materials symmetry, uniqueness of the solution, solution of two-dimensional elasticity problems. Airy stress function, application of complex variable technique in elasticity, three-dimensional elasticity problems, energy methods, bending theory of plates. (Same as MENG 515)

ME 517, Advanced Finite Element Method, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

An introduction to the numerical analysis calculus of variation, weak form of a differential equation, weighted residual techniques, solution of one-dimensional problems by the finite element method, bending problems, Lrange and Hermite interpolation functions, isoparametric elements, numerical integration, two-dimensional problems, solution of Poisson and Laplace equations, triangular and quadrilateral elements, elasticity problems, theorem of minimum potential energy stiffness matrix, examples. (Same as MENG 517)

ME 520, Fracture Mechanics, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

An introduction to the theory of elasticity, singular stress fields, Westergaard method, complex variable technique, stress intensity factor, fracture energy, numerical and experimental methods in determination of stress intensity factor, fracture toughness, J-integral Elasto-plastic fracture. (Same as MENG 520)

ME 521, Advanced Minerals Exploration, 3 cr, 3 cl hrs

Prerequisite: ME 360 or consent of instructor

Practical application of geologic, geochemical, and geophysical exploration techniques to ore search. Remote sensing technology and integration into grassroots exploration programs. Recent developments in geophysical and geochemical prospecting. Case histories. Field application of mineral exploration techniques.

ME 522, Advanced Mineral Exploration Field Mapping, 3 cr, 2 cl hrs, 2 lab hrs

Prerequisite: ME 360 or consent of instructor

Detailed mapping of mineral deposits and prospects in collaboration with professional exploration geologists and engineers with application to minerals exploration. Design and implementation of orientation surveys. Field studies will include geochemical and geological laboratory analysis. Written reports and oral presentation of projects will be reviewed by professionals.

ME 523, Ore Petrography, 3 cr, 3 cl hrs

Prerequisite: EARTH 203 or consent of instructor

Identification and description of opaque and semi-opaque minerals using polished sections complemented by reflected-light petrographic techniques. Sampling techniques for exploration, mining, and environmental remediation purposes. Preparation of polished samples from rock, rock chip, ore concentrate, and tailings sample types. Heavy liquid separation techniques for concentration of heavy minerals and quantitative mineral analyses.

ME 525, Rock and Soil Plasticity, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

Introduction to the theory of elasticity, Tresca, Von Mises and Mohr-Coulomb failure criteria, flow rule, hardening, softening and perfect plasticity, method of characteristics in solving plasticity problems, kinematics and velocity discontinuity, plastic limit analysis, upper- and lower-bound theorems, examples in soil and rock mechanics.

ME 531, Advanced Foundation Design and Analysis, 3 cr, 3 cl hrs

Prerequisite: ME 420 or consent of instructor

Advanced foundation design. Design of construction projects including but not limited to highways, airports, landfills, and slopes. Application of geosynthetics in design. Causes and remediation of structural cracking and foundation failures. Legal aspects. Case studies.

ME 534, Advanced Drilling and Blasting Engineering, 3 cr, 3 cl hrs

Prerequisite: Graduate standing or consent of the instructor

Application of explosives to rock fragmentation; theory of detonation and mechanisms of rock failure, dynamics, and propagation. The effects of rock properties on breakage. Blasting systems and production blasting techniques used in both surface and underground designs, environmental considerations and regulations. Principles of blasthole drilling and drill performance. Drilling and blasting economics.

ME 535, Stability of Rock Slopes, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisite: ME 420 or consent of instructor

Basic mechanics of slope failure. Field exploration and presentation of geological data. Shear strength of rock and rock discontinuities. Groundwater pressure and flow. Plane, wedge, circular, and toppling failure. Improvement of slope stability by drainage and support. Monitoring of slope displacements. Shares lecture with ME 435, with additional expectations for graduate credit.

ME 537, Design and Construction of Underground Openings, 3 cr, 3 cl hrs

Prerequisite: ME 420 or consent of instructor

Rock mass classification systems. Empirical design and support selections, stand-up times, block stability, and structural analysis. Elasto-plastic strain around openings. Ground reaction and response. Rock bolting and rock-support interaction analysis. Shares lecture with ME 437, with additional expectations for graduate credit.

ME 540, Computer Application in Geotechnical Engineering, 3 cr, 3 cl hrs

Prerequisites: ME 420 or 506; ME 422 or 508; basic computer skills

Computer programming using MATLAB, image processing and its applications in geotechnical engineering, introduction to finite difference and finite element methods with applications to various problems in geomechanics including steady, consolidation, slope stability, design of foundations, and underground excavations.

ME 541, Ground Improvement, 3 cr, 3 cl hrs

Prerequisites: ME 420 or equivalent soil mechanics

Principles of ground improvement; mechanical modification including shallow compaction, dynamic deep compaction, vibro-flotation, and compaction by using explosives; hydraulic modification; modification by inclusions and confinement; physical and chemical modification.

ME 545, Vibration Analysis and Control, 3 cr, 3 cl hrs

Prerequisite: ME 434 or consent of instructor

Characteristics and analysis of vibrations from mining and construction blasting, heavy equipment and transient loads. Prediction of ground motions, air blast, and frequency; response spectra, structural response and damping. Damage analysis and prediction; probabilistic study of cracking. Human response. Vibration monitoring equipment and control.

ME 546, Detonation Theory, 3 cr, 3 cl hrs

Prerequisite: MENG 549 or ME 549; or consent of instructor. MENG 556 is recommended.

Development of classical detonation model for full-order detonation of secondary explosives. Ideal versus non-ideal detonation. Burn-rate models for pyrotechnics. The concept of deflagration to detonation transition. (Same as MENG 546)

ME 548, Rock Fracturing and Fragmentation by Explosives, 3 cr, 3 cl hrs

Prerequisite: Graduate or senior standing or consent of instructor

Fundamentals of dynamic rock strength, mechanisms of fracturing and fragmentation of rocks by explosives. Theoretical treatment of rock stress induced by internal explosion, methods for computer calculations of rock damage. Brief overview of devices, accessories, and methods used in industrial applications of fragmentation.

ME 549, Wave Propagation, 3 cr, 3 cl hrs

Prerequisite: MENG 545 or ME 545 and MATH 335; or consent of instructor

An in-depth study of the propagation of waves in various media. The derivation and application of the Rankine-Hugoniot jump equations. The concept of the rarefaction wave and various wave interactions. Derivation and application of the Mie-Grüneisen equation of state. The differential form of the conservation equations, as well as some numerical solutions for simple cases. Shares lecture with EXPL 412, with additional expectations for graduate credit. (Same as MENG 549)

ME 550, Advanced Explosives Engineering, 3 cr, 3cl hrs

Prerequisites: MENG 549 or ME 549; or consent of instructor.

The detonation of non-ideal explosives, equation of state for porous media, shaped charge effect and explosively formed projectiles. Shock compaction of powders, explosive welding and experimental methods used in the evaluation of explosives and their applications. The dynamic fracture of ductile and brittle materials. (Same as MENG 550)

ME 551, Industrial Minerals, 3 cr, 3 cl hrs

*Prerequisite: Graduate standing or consent of instructor
Offered alternate years*

Study of basic concepts of production and use of industrial minerals in modern society. Emphasis on complex interactions between economics, geology, processing, marketing, and transportation. Selected industrial minerals studies in detail. Several field trips to operations and occurrences. (Same as GEOL 551)

ME 552, Applied Explosives Engineering, 3 cr, 3 cl hrs

Prerequisite: Graduate or senior standing or consent of instructor

Commercial and other applications of explosives. Basics of thermal decomposition, explosion, shock initiation, and detonation. Laboratory methods of performance evaluation of explosives including shock initiation tests and underwater explosion tests. Techniques of forming and shaping of detonation waves. Some unusual applications of explosives in creating large magnetic fields.

ME 553, Computer Modeling of Detonations, 3 cr, 3 cl hrs

Prerequisite: MENG 549 or ME 549; or consent of instructor. MENG 517/ME 517 is recommended.

Introduction to hydrodynamic modeling applied to explosives. Numerical methods for modeling shock physics, detonation, and material response. Finite difference, finite element and smoothed particle hydrodynamic methods, equation of state and strength models, and numerical fracture and fragmentation. (Same as MENG 553)

ME 561, Advanced Topics in Engineering Geology, 3 cr, 3 cl hrs

Offered on demand

Study of special topics in geologic hazards, site characterization, and related fields of interest in engineering geology.

ME 562, International Mining Field Trip, 3 cr, 3 cl hrs

Field trip in conjunction with the Student Chapter of the Society of Economic Geologists to a geologic and mining interest in a foreign country, usually Chile. Seminar-style class with a required term paper. Students are responsible for preparation of a field-trip guidebook, to be used by students and professionals participating in the field trip.

ME 563, Field Studies in Hydrothermal Alteration, 3 cr, 3 cl hrs

Prerequisites: EARTH 211, 318 or 319 or equivalent; ME 360 or EARTH 480

A field and lab-based course emphasizing the geochemistry and mineralogy of hydrothermal ore deposits, with substantial hands-on exercises and field-based descriptive work. Lab exercises utilize thin section and polished section samples from hydrothermal ore deposit suites to demonstrate variations in protolith and alteration mineralogy, and result in the production of professional-style reports, interpreting the geochemical and exploration significance of the alteration assemblages observed. Field trips to mineral deposits emphasize the areal extent of hydrothermal alteration associated with porphyry, epithermal and skarn-style ore deposits.

ME 564, Economic Geology Field Camp, 1-4 cr to be arranged

Prerequisites: EARTH 353, ME 360 or equivalent

Field-based course emphasizing detailed mapping of mineral deposits and preparation of professional-style reports. Field areas comprise of distinct ore deposit settings, and involve description and recognition of rock types, alteration assemblages, and ore-related minerals. mapping in operating mines, and at prospects. Preparation of professional-style Executive Summary reports required. In autumn to be held in western U.S.; summer course to be held in western U.S. and in eastern U.S. in alternate summers.

ME 565, Mine Waste Characterization, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Environmental aspects of mine waste materials. Geologic, geochemical, and engineering evaluation of tailings, waste rock dumps, and processing chemicals. Sampling and mineralogic analysis of mine wastes. Characterization of physical, chemical, and biological environments surrounding mine sites. Current environmental and mining regulations. Field trips, laboratory studies, and case histories.

ME 566, Mine Waste Management and Control, 3 cr, 3 cl hrs

Prerequisite: ME 565

Control of wastewater and solid pollutants from mining and processing of minerals. Design of facilities to control and manage waste streams resulting from mine and mill operations. Mine land reclamation and closure design. Design projects and field trips.

ME 570, Advanced Topics in Explosives Engineering, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Study of special topics in the application of explosives in the fields of rock blasting, structure response to vibrations, and ordnance.

ME 571, Advanced Topics in Mineral Engineering, 2-3 cr**ME 572, Graduate Seminar, 1 cr, 2 cl hrs**

Prerequisite: Graduate standing

Presentation and discussion of research ideas, including presentation of published papers.

ME 581, Directed Study, 1-3 cr**ME 590, Independent Study, cr to be arranged**

Independent research organized and conducted by the student under the direction of the student's advisor. Written final report and oral presentation required.

ME 591, Thesis (master's program), cr to be arranged

Faculty Research Interests

Chávez—Applied Mineral Exploration, Ore Deposits, Natural Resource Utilization

Fakhimi—Geomechanics, Numerical Modeling

Gundiler—Hydrometallurgy and Mineral Processing

McLemore—Economic Geology

N. Mojtabai—Site Investigation, Rock Fragmentation, Mine Design, Geomechanics

Razavi—Soil Mechanics, Image Processing, X-Ray computer Tomography

Oravec—Rock Mechanics, Surveying

C. Wimberly—Natural Resources Law

Petroleum Engineering

Professors Engler, Lee

Associate Professors Chen, Leclerc (Chair of the Department)

Assistant Professor Kelly, Lin, Nguyen, Rahnema

Adjunct Faculty: Balch, Buckley, Grigg, Huang,

Martin, Lorenz, Plisga, Ruan, Seright, Warpinski

Degrees Offered: B.S. in Petroleum and Natural Gas Engineering, M.S. and Ph.D. in Petroleum Engineering

Petroleum and natural gas engineering is a broad-based discipline primarily concerned with the development, exploration, and conservation of oil and gas resources. Petroleum and natural gas engineers plan and supervise drilling and well-completion programs, design and select drilling and production equipment, optimize the production of oil and natural gas, estimate reserves, and manage oil and gas properties.

The oil and gas industry is a progressive and highly technical business, which offers opportunities to young engineers, both in the United States and abroad. A petroleum and natural gas engineering graduate may obtain a responsible position with an oil company, establish a consulting business, or become an independent oil producer.

Program Educational Objectives

The mission of the Petroleum Engineering program is to prepare students for the challenges of such a diversified career by providing students with the necessary skills to achieve success in their future profession. To achieve this mission, the following educational objectives are emphasized:

- Our graduates will use their highly competitive skills in a range of engineering career paths to become leaders in the energy industry.
- Our graduates will seek out continuing education opportunities, striving for technical excellence
- Our graduates will leverage evolving technology through collaborative engagement in both industry workshops and professional societies.

By graduation, a student will be capable of solving a variety of petroleum engineering problems and be able to integrate petroleum engineering concepts to a practical design project.

Undergraduate Program Bachelor of Science in Petroleum and Natural Gas Engineering

Minimum credit hours required—134

In addition to the General Education Core Curriculum (page 7), the following courses are required:

- PETR 101 (1), 111 (1) 245 & 245L (4), 311 & 311L (4), 345 & 345L (4), 370 (3), 413 & 413L (4), 424 & 424L (4), 425 (3), 445 (3), 450 (2), 470 (3), 471(2), 472 (2)
- ES 201 (3), 216 (3), 302 (3), 303 (3), 316 (3), 332 (3), 347 (3)
- MATH 231 (4), 335 (3)
- EARTH 101 & 103L (4), 460 (3)
- EARTH 202 (4) or EARTH 203 (3). EARTH 203 recommended.
- Technical Electives: Three credit hours of upper-division technical and petroleum and natural gas engineering electives are selected by the student with the faculty advisor's approval to fulfill the requirement of 134 credit hours needed for graduation.

Petroleum and natural gas engineering majors must obtain a C or better in all petroleum engineering courses to graduate.

Only courses in Areas 4, 5, and 6 of the general education core curriculum requirements (page 7) may be taken on an S/U basis.

Sample Curriculum for the Bachelor of Science in Petroleum and Natural Gas Engineering

Semester 1

- 1 PETR 101 (intro)
- 4 MATH 131 (calculus)
- 4 CHEM 121 & 121L (general)
- 3 ENGL 111 (college English)
- 4 EARTH 101 & 103L (earth processes)
- 16 Total credit hours

Semester 2

- 4 MATH 132 (calculus)
- 1 PETR 111 (Comp applications)
- 5 PHYS 121 & 121L (general)
- 3 ENGL 112 (college English)
- 3 Social Science/Humanities
- 16 Total credit hours

Semester 3

- 4 MATH 231 (calculus)
- 4 CHEM 122 & 122L (general)
- 5 PHYS 122 & 122L (general)
- 3 ES 201(statics)
- 16 Total credit hours

Semester 4

- 4 PETR 245 & 245L: (petroleum fluids)
- 3 MATH 335 (ordinary differential equations)
- 3 ES 216 (fluid mechanics)
- 3 ES 302 (mechanics)
- 3 ES 347 (thermodynamics)
- 3 EARTH 203 (Earth's crust)
- 19 Total credit hours

Semester 5

- 4 PETR 311 & 311L (drilling)
- 4 PETR 345 & 345L (reservoir engineering I)
- 3 ES 303 (dynamics)
- 3 ENGL 341 (technical writing)
- 3 Social Science/Humanities
- 17 Total credit hours

Semester 6

- 3 PETR 370 (formation evaluation)
- 2 PETR 450 (well testing)
- 4 PETR 413 & 413L (well design)
- 3 PETR 445 (reservoir engineering II)
- 3 EARTH 460 (subsurface geology)
- 3 Social Science/Humanities
- 18 Total credit hours

Semester 7

- 4 PETR 424 & 424L (production engineering)
- 3 PETR 470 (reservoir simulation)
- 2 PETR 471 (reservoir description)
- 3 ES 316 (economics)
- 3 Social Science/Humanities
- 15 Total credit hours

Semester 8

- 3 PETR 425 (well completions)
- 2 PETR 472 (reservoir management)
- 3 ES 332 (electrical)
- 3 Technical Elective
- 3 Humanities/Social Science
- 3 Humanities/Social Science
- 17 Total credit hours

Minor in Petroleum Engineering

Minimum credit hours required—18

The following courses are required:

- PETR 245 (3), 311 & 311L (4), 345 & 345L (4), 424 & 424L (4),
- At least one of the following: PETR 413 (3), 445 (3)

Graduate Program

The Petroleum Engineering program offers two options for a Master of Science Degree—with thesis or independent study—and a Doctor of Philosophy degree. All graduate students are required to register for and attend the Graduate Seminar (PETR 570) each semester it is offered. Exceptions may be made only with approval of the student's advisor and the department chair.

The Ph.D. and master's programs are open to students with degrees in fields other than petroleum and natural gas engineering. A special course program will be tailored for those students who have not completed a B.S. in petroleum and natural gas engineering to provide an appropriate background. Prospective students are encouraged to visit www.nmt.edu/~petro for more details.

Master of Science in Petroleum Engineering**Thesis Option**

The master's program requires a minimum of 24 credit hours of coursework and 6 credit hours of thesis. The courses are designed to advance the student's knowledge in topics of petroleum engineering. The research thesis provides a means to do independent and analytical thinking on a specific subject. The student's course of study must be approved by the student's advisory committee and the department chair and must fulfill the general requirements for the master's degree.

Independent Study Option

Candidates for the non-thesis Master of Science option must complete a total of 36 credit hours, of which a minimum of three (3) credit hours must be independent study (PETR 590). At least 18 of the credit hours must be from graduate-level Petroleum Engineering courses, excluding PETR 581 and 590. The student's course of study must be approved by the student's advisory committee and must fulfill the general graduate requirements for the master's degree without thesis. The final outcome of the independent study is to submit a formal paper followed by an oral presentation to the advisory committee.

Doctor of Philosophy in Petroleum Engineering

In order to be admitted to the Ph.D. program, a student must meet the requirements as set forth by the Graduate Program and have completed an M.S. degree with thesis. A minimum of 60 credit hours past the master's degree is required. New Mexico Tech courses taken to satisfy this requirement must have content different from courses applied to previous degrees. In addition to the department administered preliminary examination, the student is required to successfully complete a candidacy examination and a defense of the dissertation administered by the student's advisory committee. (See www.nmt.edu/~petro for more detailed information.)

The 60-credit requirements should be distributed as follows:

1. Minimum 30 credits regular* courses and Directed Study (581).
 - Minimum 12 credits of regular* 500-level petroleum engineering courses.
 - Maximum 9 credits of Directed Study (PETR 581); maximum 6 credits from the same professor.
 - Minimum 6 credits from outside of petroleum engineering in either engineering, engineering management, or science disciplines. Students with degrees in disciplines other than Petroleum Engineering may take an additional 6 credits of petroleum engineering courses instead.
 2. Minimum 24 credits and maximum 30 credits of Dissertation (PETR 595).
 3. Registration in Graduate Seminar (PETR 570) is required.
- * Courses are considered regular only if a course title and scheduled meeting time are specified and the course is open to all qualified students.

Petroleum Engineering Courses

PETR 101, Introduction to Petroleum Engineering, 1 cr, 1 cl hr

Introduction to energy supply and demand. Define reservoir, drilling and production aspects of petroleum engineering. Included are professionalism and ethics in the work environment.

PETR 111, Computer Applications for Petroleum Engineering, 1 cr, 3 lab hrs

Corequisite: MATH 104

Development of algorithms in Excel™ to solve petroleum engineering problems: gas z-factor, static and flowing gradients, pump design, well testing functions and others.

PETR 245, 245D, Petroleum Fluids, 3 cr, 3 cl hrs

Prerequisites: CHEM 122; MATH 132

Corequisite: PETR 111

Characteristics and properties of reservoir fluids. Representation of fluid property data for computer uses with models and regression.

PETR 245L, Petroleum Fluid Laboratory, 1 cr, 3 lab hrs

Corequisite: PETR 245

Characterize pressure, volume and temperature relationships using virtual simulation and Laboratory measurement of reservoir fluid properties.

PETR 311, Drilling Engineering, 3 cr, 3 cl hrs

Prerequisite: ES 216

Corequisite: ES 302

Introduction to drilling engineering through the study of rig equipment functions. Engineering analysis of drill string buoyancy, drilling mud circulation and flow hydraulics, drill string components, and well control. Preliminary discussion of pore and fracture pressure gradients. Well plan profile including drill bit selection, drilling fluid selection, drill string component section, and well control.

PETR 311L, Drilling Mud Laboratory, 1 cr, 3 lab hrs

Corequisite: PETR 311

The composition, measurement, and design of the properties of drilling fluids.

PETR 345, Reservoir Engineering I, 3 cr, 3 cl hrs

Corequisites: PETR 245

Properties of reservoir rocks and homogeneous and multiphase fluid flow in reservoirs. Capillary phenomena, relative permeability, compressibility, and fluid saturation distribution. Material balances. Statistical analysis using regression, probability concepts, and computer applications to reservoir data.

PETR 345L, Reservoir Engineering Laboratory, 1 cr, 3 lab hrs

Corequisite: PETR 345

Laboratory measurement of reservoir fluid/rock properties, PVT, and core analysis. Computer data analyses using statistical techniques including probability concepts, regression, and optimization.

PETR 370, Formation Evaluation, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: PHYS 122; PETR 345

Introduction to logging tool principles and operation. Evaluation of reservoir properties and interpretation of open hole well logs. Multiwell correlations with application to volumetric calculations. Lab exercises on reservoir mapping and well log case studies. (Same as EARTH 370)

PETR 411, Advanced Drilling, 3 cr, 3 cl hrs

Prerequisite: PETR 311 or consent of instructor

Drilling operations technology with an emphasis on field practices and techniques. Advanced topics including drilling fluids rheology and hydraulics. Mechanics of BHA in vertical and directional holes. Directional well trajectory predictions and design. Modeling of drag and torque. Dynamics of drill string, wellbore measurements, deepwater drilling and heat transfer in wells.

PETR 413, Well Design, 3 cr, 3 cl hrs

Corequisite: PETR 311

Details of the development of pore and fracture pressure gradients. Casing depths using pore and fracture pressure gradients plots. Review of engineering analysis for casing string design. Selection of casing, cement class and well cementing equipment and methods. Development of detailed well plan for drilling and completion of oil and gas wells. Directional and horizontal drilling and drillstring design.

PETR 413L, Well Design Lab, 1 cr, 3 lab hrs*Corequisite: PETR 413*

The composition, testing, and design of cement slurries and fracturing fluids.

PETR 424, Production Engineering, 3 cr, 3 cl hrs*Prerequisite: PETR 345, ES 216*

Elements of producing oil and gas wells. Flow of single and multiphase fluids in vertical and horizontal pipes. Choke performance. Nodal analysis systems approach to well production performance optimization. Production decline analysis using exponential, harmonic, and hyperbolic decline curves applied to actual well production data. Introduction to artificial lift techniques.

PETR 424L, Production Engineering Laboratory, 1 cr, 3 lab hrs*Corequisite: PETR 424*

Design and determination of pressure losses for various components in a flow loop. Design of artificial lift systems including rod pumps, submersible pumps and gas lift.

PETR 425, Well Completion, 3 cr, 3 cl hrs*Prerequisite: PETR 345**Corequisite: PETR 413*

Well completion methods. Design and selection of tubing; perforating performance; sand, water and gas control. Introduction to stimulation operations, selection of stimulation techniques, design of acid and hydraulic fracture treatments.

PETR 440, Directional Drilling & Innovative Drilling Methods, 3 cr, 3 cl hrs*Prerequisites: PETR 311*

Two and three dimensional directional well path design; horizontal drilling; mathematical model deflection tool analysis; 2D and 3D vector application; down-hole motors and MWD techniques; underbalanced drilling; casing while drilling; coiled-tubing drilling.

PETR 441, Natural Gas Reservoir Engineering, 3 cr, 3 cl hrs*Prerequisite: PETR 345*

Estimation of gas reserves for dry and gas condensate reservoirs. Evaluation of deliverability tests and subsequent development of flow equations. Determination of gas recovery from unconventional reservoirs; e.g., coalbed methane, tight gas sands, shales. Strategies for gas field development. Additional work is required at graduate level.

PETR 443, Underbalanced Drilling and Completions, 3 cr, 3 cl hrs*Prerequisite: PETR 311*

Air and gas, aerated, and stable foam drilling and completions operations. Development of basic calculational theory and application to operational problems. Emphasis on the planning of successful drilling and completions operations. Selection of appropriate field equipment for drilling and completions operations. Solution of drilling and completions field problems.

PETR 445, Reservoir Engineering II, 3 cr, 3 cl hrs*Prerequisite: PETR 345*

Advanced reservoir engineering principles and applications including material balances, decline curve analysis, unsteady flow in porous media, partial penetration, water influx, reservoir heterogeneity, fractional flow, and frontal advance.

PETR 446, Improved Petroleum Recovery, 3 cr, 3 cl hrs*Prerequisite: PETR 445 or consent of instructor*

Water flooding techniques. Water handling. Injection and production well patterns. Productive techniques for economic operations. Introduction to enhanced oil recovery; polymer, surfactant, thermal and miscible flooding.

PETR 450, Well Testing, 2 cr, 2 cl hrs*Prerequisite: PETR 345*

Design well testing program to meet specific guidelines. Apply conventional well test data to estimate the reservoir's capacity to transmit fluids, the reservoir's energy, and the effectiveness of the well completion. Both Pressure Transient (PTA) and Rate Transient (RTA) analysis will be studied.

PETR 460, Numerical Simulation, 3 cr, 3 cl hrs*Prerequisite: PETR 445*

Application of finite difference and finite element techniques for solving reservoir engineering problems.

PETR 470, Applied Reservoir Simulation, 3 cr, 2 cl hrs, 3 lab hrs*Prerequisites: PETR 345*

Use reservoir simulator for numerical modeling of petroleum engineering problems beyond classical approaches. Introduction to simulation fundamentals, work with post- and pre-processing software, design and construct black oil, compositional and thermal models. History matching, predict and optimize well performance.

PETR 471, Reservoir Description, 2 cr, 2 cl hrs

Prerequisites: PETR 370, 445; EARTH 460

Corequisite: PETR 424

Offered fall semester

Applied characterization of a field project through integration of reservoir, production and geological data. Well performance and production optimization.

PETR 472, Reservoir Management, 2 cr, 2 cl hrs

Prerequisite: PETR 471; ES 316

Offered spring semester

Economic analysis of petroleum-producing properties; evaluation of reservoir management decisions for oil and gas development; establishing the effect of risk and uncertainty on economic evaluation.

PETR 478, Petroleum Seminar, variable credit, 2 cl hr

Prerequisite: Senior standing or consent of instructor

Current topics in petroleum and natural gas engineering. Techniques of oral presentation of research and development data.

PETR 491, Special Problems in Petroleum and Natural Gas Engineering, 1–3 cr as arranged

Prerequisite: Senior standing or consent of instructor

Individual studies in petroleum and natural gas engineering problems of special interest.

PETR 523, Numerical Simulation, 3 cr, 3 cl hrs

Prerequisite: PETR 445 or consent of instructor; ability to write a computer program

The simulation of subsurface fluid reservoirs using numerical models.

PETR 524, Fluid Flow in Porous Media, 3 cr, 3 cl hrs

Prerequisites: PETR 445 or consent of instructor.

Physical concepts involved in the flow of fluids in porous media; aspects of Darcy's Law; multiphase flow concepts of relative permeability and capillary pressure.

PETR 532, Advanced Well Stimulation, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

Theories of hydraulic fracturing, mechanics of fracturing, rheology of fracturing fluids, acid fracturing treatment, models for matrix acidizing, evaluation of stimulation operations.

PETR 537, Petroleum-Related Rock Mechanics, 3 cr, 3 cl hrs

Studies of theories and applications of rock mechanics to petroleum engineering. Topics include laboratory measurements of porosity, permeability, and deformation behavior as a function of stress state, in situ stress measurements, wellbore stability, sand control, and reservoir compaction/subsidence.

PETR 541, Natural Gas Reservoir Engineering, 3 cr, 3 cl hrs

Prerequisite: PETR 345

Estimation of gas reserves for dry and gas condensate reservoirs. Evaluation of deliverability tests and subsequent development of flow equations. Determination of gas recovery from unconventional reservoirs; e.g., coalbed methane, tight gas sands, shales. Strategies for gas field development. Additional work is required at graduate level.

PETR 544, Advanced Reservoir Engineering, 3 cr, 3 cl hrs

Prerequisite: PETR 445 or consent of instructor

Studies of natural water drive reservoirs in finite and infinite aquifers. Transient pressure behavior in heterogeneous reservoirs. Material Balance Equations from advanced viewpoint.

PETR 545, Advanced Production Design, 3 cr, 3 cl hrs

Prerequisite: PETR 425 or consent of instructor

Oil and gas well production principles. Flowing well performance, two-phase vertical flow, theory and design of artificial lift systems.

PETR 546, Advanced Formation Evaluation, 3 cr, 3 cl hrs

Prerequisite: PETR 370 or consent of instructor

Study of physical and textural properties of reservoir rocks which provide a link between reservoir engineering and well logging. Advanced exploration and production logging. Estimation of geological environment. Quantitative reservoir evaluation in different lithologies from log data. New logging techniques.

PETR 547, Naturally Fractured Reservoirs, 3 cr, 3 cl hrs

Geological characterization and reservoir simulation of naturally fractured reservoirs. Description of natural fractures and fracture systems from surface outcrops, core analysis, log interpretation, and well testing. Fluid-flow simulation of fractured reservoirs using numerical models.

PETR 548, Reservoir Geomechanics, 3 cr, 3 cl hrs

Prerequisites: PETR 445 or consent of instructor

Fundamentals and issues of coupled fluid-flow/thermal/geomechanics associated with hydrocarbon production. Topics include elasticity, poroelasticity, thermo-poroelasticity, reservoir stress depletion/rebound, productivity of stress-sensitive reservoirs, and waterflood-induced fracturing.

PETR 552, Fluid/Surface Interactions, 3 cr, 3 cl hrs

Prerequisite: Consent of instructor

The physics and chemistry of interfaces, focusing on the behavior of multifluid systems both in the presence and absence of solids. How basic interactions among microscopic particles can explain macroscopic phenomena. Application-oriented, focusing on interactions important in hydrology, petroleum engineering, and environmental engineering. (Same as HYD 552)

PETR 554, Advanced Natural Gas Engineering, 3 cr, 3 cl hrs

Prerequisite: PETR 464 or consent of instructor

Gas flow in vertical and inclined pipes, surface facilities, gas processing, overall transportation requirements.

PETR 556, Advanced Drilling, 3 cr, 3 cl hrs

Prerequisite: PETR 311

The following topics will be covered in this class: directional and horizontal drilling, drag and torque modeling, advanced wellbore hydraulics, and innovative drilling methods including underbalanced drilling, casing drilling and coil tubing drilling.

PETR 557, Advanced Artificial Lift Methods, 3 cr, 3 cl hrs

Prerequisite: PETR 424

Offered Fall Semester

This class will cover most of the common artificial lift methods in oil and gas industry including: Electrical Submersible Pump (ESP), Gas Lift, Rod Sucker Pump, Plunger Lift, and Progressive Cavity Pump.

PETR 558, Advanced Topics in Enhanced Oil Recovery Methods, 3 cr, 3 cl hrs

Prerequisite: PETR 446 or consent of instructor

Advanced topics may include surfactant and alkali flooding mechanisms. Polymer flooding and rheology of non-Newtonian fluids. Gas injection methods including carbon dioxide, hydrocarbons, and nitrogen. Thermal recovery.

PETR 560, Phase Behavior of Petroleum Fluids, 3 cr, 3 cl hrs

Prerequisite: PETR 245 or consent of instructor

Use of equations of state for predicting PVT behavior of complex petroleum fluids. Emphasis on the descriptions of fluids used in simulating gas injection recovery processes and multiphase flow in pipes. Correlations for phase viscosity and interfacial tension.

PETR 564, Advanced Well Testing, 3 cr, 3 cl hrs

Prerequisite: PETR 370 or consent of instructor

The partial differential equations for liquid and gas flow in porous media, boundary conditions including skin and well-bore storage effects. Applications of Laplace transformation. Pressure buildup and drawdown tests.

PETR 570, Graduate Seminar, 1 cr, 2 cl hrs

Prerequisite: Senior or graduate standing

Presentation and discussion of research ideas. Review of recently published papers/new concepts.

PETR 571, 572, Advanced Topics, 2–3 cr, 2–3 cl hrs

Offered on demand

Prerequisite: Consent of instructor

Special topics in petroleum and natural gas engineering.

PETR 581, Directed Study, 1–3 cr each semester

Prerequisite: Consent of instructor

Research and literature survey as directed by advisor on subjects of interest pertaining to petroleum and natural gas engineering.

PETR 590, Independent Study, 1–3 cr

Independent research organized and conducted by the student under the direction of the student's advisor. Written final report and oral presentation required.

PETR 591, Thesis (master's program), cr to be arranged**PETR 595, Dissertation (doctoral degree program), cr to be arranged**

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Faculty Research Interests

Balch—Fuzzy Expert Systems, Data Mining

Bretz—Transport Phenomena, Phase Behavior, Natural Gas Processing

Buckley—Petrophysics and Surface Chemistry, Reservoir Wettability

Chen—Well Testing, Reservoir Mechanics

Engler—Formation Evaluation, Petrophysics, Unconventional Gas Recovery, Stimulation

Grigg—Gas Flooding Processes, Phase Behavior

Kelly—Reservoir Evaluation and Management

Lee—Natural Gas Storage, Applied Numerical Methods, Phase Behavior, Membrane Technology

Lin—production well performance, horizontal well analysis

Lorenz—Petroleum Geology

Martin—Reservoir Management, EOR

Nguyen—Drilling Fluids, Multiphase Flow and Artificial Lift

Plisga—Production Operations

Rahnema—Simulation/Modeling, IOR, Reservoir Phase Behavior

Ruan—Design of Web-Based Systems

Sright—Profile Control; Polymer, Water, and Chemical Flooding

Warpinski—Hydraulic Fracturing, In-Situ Stresses, Natural Fractures, Geomechanics, Rock Mechanics

Administration, Faculty, and Professional Staff

Board of Regents

Jerry A. Armijo
David Gonzales
Donald Monette
Deborah Peacock
Myissa Weiss—Student Regent

Administration

President.....**Daniel H. López**
 Vice President for Academic Affairs.....**Warren Ostergren**
 Vice President for Administration
 and Finance.....**Lonnie Marquez**
 Vice President for Student and
 University Relations.....**Melissa Jaramillo-Fleming**
 Vice President for Research and
 Economic Development.....**Van Romero**
 Director, New Mexico Bureau of Geology
 and Mineral Resources.....**L. Greer Price**
 Director, New Mexico Petroleum
 Recovery Research Center.....**Robert L. Lee**
 Director, Energetic Materials Research
 and Testing Center (EMRTC).....**Richard Jimenez**
 Dean of Arts & Sciences.....**William D. Stone**
 Dean of Engineering.....**Kevin Wedeward**
 Dean of Graduate Studies.....**Lorie Liebrock**
 Dean of Students.....**Melissa Jaramillo-Fleming**

Academic Department Chairs

Biology.....**Snezna Rogelj**
 Chemistry.....**Jeffrey Altig**
 Civil and Environmental Engineering.....**Clint Richardson**
 CLASS.....**Steve Simpson**
 Computer Science, Engineering.....**Dongwan Shin**
 Earth and Environmental Science.....**Penelope Boston**
 Electrical Engineering.....**Kevin Wedeward**
 Management.....**Frank Reinow**
 Materials Engineering.....**Nikolai Kalugin**
 Mathematics.....**Ivan Avramidi**
 Mechanical Engineering.....**Andrei Zagrai**
 Mineral Engineering.....**Navid Mojtabei**
 Petroleum and Chemical Engineering.....**Corey Leclerc**
 Physics.....**Michelle Creech-Eakman**
 Psychology and Education.....**Mark Samuels**

Department Directors

Academic Affairs.....**Warren Ostergren**
 Academic Center for Technology.....**Iver Davidson**
 Admission.....**Anthony Ortiz**
 Advancement.....**Colleen Guengerich**
 Affirmative Action and Compliance.....**Randy Saavedra**
 Auxiliary Services.....**Valerie Del Curto**
 Bookstore.....**Scott Botko**
 Budget and Analysis.....**Leyla Sedillo**
 Bureau of Geology.....**L. Greer Price**
 Business Office.....**Anna McLain/Arleen Valles**
 Campus Dining.....**Kevin Chafins**
 Campus Police.....**Scott Scarborough**
 Career Services.....**Michael Voegerl**
 Child Care Center.....**Karen Crane**
 Community Education.....**Lillian Armijo**
 Cooperative Education.....**Michael Voegerl**
 Counseling Services.....**Janet Ward**
 EMRTC.....**Richard Jimenez**
 Facilities Management.....**Yvonne Manzano**
 Geophysical Research Center.....**Van D. Romero**
 Golf Course.....**Russell Moore**
 Graduate Studies.....**Lorie Liebrock**
 Gymnasium.....**Melissa Begay**
 Health Services.....**Susan Lewark**
 Human Resources.....**JoAnne Salome**
 ICASA.....**Richard Jimenez**
 Information Technology & Communication.....**Joe Franklin**
 Instrument Room.....**Edward Gangemi**
 International and Exchange Services.....**Michael Voegerl**
 IRIS/PASSCAL Instrument Center.....**Bruce C. Beaudoin**
 Langmuir Laboratory.....**Ken Eack**
 Library.....**Lisa Beinhoff**
 Macey Center.....**Nowka Leviner**
 Multicultural Programs.....**Michael Voegerl**
 Office for Student Learning.....**Lisa Majowski**
 Performing Arts.....**Ronna Kalish**
 Post Office.....**Sam Chavez**
 President's Office.....**Daniel H. López**
 Property Office.....**Steven Hicks**
 PRRC.....**Robert L. Lee**
 Public Information.....**Thom Guengerich**
 Purchasing Services.....**Kimela Miller**
 Registrar.....**Sara Grijalva**
 Research and Economic Development.....**Van D. Romero**
 Residential Life.....**Mitchell Tappen**
 Science Fair and Olympiad.....**Rose Baca-Rivet**
 Student Affairs.....**Michael Voegerl**

Faculty and Professional Staff

Key: *NMBGMR, New Mexico Bureau of Geology and Mineral Resources; PRRC, New Mexico Petroleum Recovery Research Center; ICASA, Institute for Complex Additive Systems Analysis; MRO, Magdalena Ridge Observatory; ACT, Academic Center for Technology; EMRTC; Energetic Materials Research and Testing Center*

Emma Aafloy, Associate Director for Budget, Administration and Finance

B.S., New Mexico Institute of Mining and Technology

Robert Abernathy, Computational Analyst, EMRTC; Adjunct Faculty, Mechanical Engineering

B.S., Ph.D., New Mexico State University

Rakhim Aitbayev, Associate Professor of Mathematics
Higher Education Diploma, Candidate of Sciences, Kazakh State University, USSR; Ph.D., University of Kentucky

Kenneth Aerts, Assistant Director for Financial Aid
B.B.A., New Mexico State University

Bruce Allen, Field Geologist (NMBGMR)
B.S., Ph.D., University of New Mexico

Jeff Altig, Associate Professor of Chemistry and Chair of the Department
B.S., University of Oregon; Ph.D., University of Wisconsin-Madison

Peter C. Anselmo, Associate Professor of Management; Adjunct Faculty, Computer Science;
Information Technology Program Coordinator; Research Scientist, ICASA
B.A., New Mexico Highlands University; M.B.A., Ph.D., University of Texas at Austin

Rene Arechiga, Associate Professor of Electrical Engineering
B.S., Instituto Politecnico Nacional; M.S., Stanford University; Ph.D., University of New Mexico

Paul Arendt, Assistant Professor of Physics
B.S., New Mexico Institute of Mining and Technology;
M.S., University of California Davis; Ph.D., New Mexico Institute of Mining and Technology

Lillian Armijo, Director of Community Education
B.B.A., M.A., New Mexico State University

Ivan Avramidi, Professor of Mathematic and Chair of the Department, Adjunct Faculty, Physics
M.S., Rostov State University, Rostov-on-Don, Russia;
Ph.D., Moscow State University, Moscow

Valentina Avramidi, Associate Director for Finance (NMBGMR)
B.S., Rostov State University, Russia

Gary Axen, Associate Professor of Geology
B.S., M.S., Massachusetts Institute of Technology; Ph.D., Harvard University

Rose Baca-Rivet, Director of Science Olympiad, Academic Affairs
B.S., New Mexico Institute of Mining and Technology

Sayavur I. Bakhityarov, Associate Professor of Mechanical Engineering
B.Sc., M.Sc., State Oil Academy, Azerbaijan; Ph.D., Institute of Thermophysics, Russia; Sc.D., Birmingham University, UK

Robert Balch, Research Scientist (PRRC), Adjunct Faculty, Petroleum Engineering and Computer Science
B.S., Evergreen State College; M.S., Ph.D., New Mexico Institute of Mining and Technology

Lynda L. Ballou, Instructor of Mathematics
B.S., Colorado State University-Pueblo; M.S., Ph.D., Kansas State University

Marvin Banks, Program Manager, Hazardous Materials Testing (EMRTC)
B.S., New Mexico Institute of Mining and Technology

Luz Diaz Barreras, Veteran's Administrator, Academic Affairs
B.S., New Mexico Institute of Mining and Technology
M.A., University of New Mexico

Noel Barstow, Staff Scientist (IRIS)
B.S., New York University; M.S., State University of New York at Stony Brook

Roy S. Baty, Adjunct Faculty, Mechanical Engineering
B.S., M.S., University of Utah; M.S., New Mexico Institute of Mining and Technology; Ph.D., Pennsylvania State University

Paul W. Bauer, Associate Director and Senior Geologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.S., University of Massachusetts; M.S., University of New Mexico; Ph.D., New Mexico Institute of Mining and Technology

Bruce C. Beaudoin, Director IRIS/PASSCAL Instrument Center
B.S., Western Washington University; M.S., Ph.D., Stanford University

George W. Becker, Coordinator, Master of Science for Teachers Program
B.S., New Mexico Institute of Mining and Technology

Melissa Begay, Director of Physical Recreation/Student Activities
B.A., M.A., New Mexico Highlands University

Nouraddine Benalil, Computer Support Specialist (PRRC)
B.S., New Mexico Institute of Mining and Technology

Susan L. Bilek, Professor of Geophysics
B.S., Pennsylvania State University; M.S., Ph.D., University of California, Santa Cruz

Douglas Bland, Economic Geologist, Special Projects (NMBGMR)
B.S., Virginia Tech; M.S., University of Wyoming

Brian Borchers, Professor of Mathematics
B.S., M.S., Ph.D., Rensselaer Polytechnic Institute

Penelope Boston, Professor of Cave and Karst Science, Chair of the Department
B.A., M.S., Ph.D., University of Colorado, Boulder

Noreen Boykin, Assistant Director of Auxiliary Services
B.S., New Mexico State University

- Ronald Broadhead**, Principal Petroleum Geologist, Head of Petroleum Section (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.S., New Mexico Institute of Mining and Technology; M.S., University of Cincinnati
- Rande Brown**, Disability Counselor for the Office of Counseling and Disability Services (OCDS)
B.S., University of Texas
- Art Bukowski**, Lecturer in Mathematics
B.S., M.S., Ohio University; Ph.D., University of New Mexico
- T. David Burleigh**, P.E., Professor of Materials and Metallurgical Engineering
B.S., Colorado School of Mines; M.Sc, Ph.D., Massachusetts Institute of Technology
- Nancy Bush**, Visiting Assistant Professor of Chemistry
B.S., New Mexico Institute of Mining and Technology; Ph.D., University of New Mexico
- Elizabeth Bustamante**, Technical Information Associate (PRRC)
B.A., Idaho State University; M.L.S., Indiana University Library School
- Daniel Cadol**, Assistant Professor of Hydrology
B.S., Whitman College; M.S., Ph.D., Colorado State University
- Paul Calvert**, Visiting Professor of Chemical Engineering
Ph.D., Massachusetts Institute of Technology
- Christian Carrico**, Associate Professor of Environmental Engineering
B.S., M.S., Ph.D., University of Illinois at Urbana-Champaign
- Richard A. Cervantes**, Associate Vice President for Research and Economic Development
B.B.A., M.S., North Texas State University
- Richard M. Chamberlin**, Senior Field Geologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.S., M.S., New Mexico Institute of Mining and Technology; Ph.D., Colorado School of Mines
- William Xavier Chávez, Jr.**, Professor of Geological Engineering
B.S., New Mexico Institute of Mining and Technology; M.A., Ph.D., University of California at Berkeley
- Her-Yuan Chen**, Associate Professor of Petroleum and Chemical Engineering
B.S., Institute of Marine Science and Technology, Taiwan; M.S., Ph.D., Texas A&M University
- Pabitra Choudhury**, Assistant Professor of Chemical Engineering
B.S., Indian Institute of Technology Bombay; M.S., Indian Institute of Technology Roorkee; M.S., Ph.D., University of South Florida
- Sanchari Chowdhury**, Visiting Assistant Professor
B.S., National Institute of Technology, Durgapur, India; M.S., Indian Institute of Technology, Roorkee, India; Ph.D., University of South Florida
- Kent C. Condie**, Professor of Geochemistry
B.S., M.A., University of Utah; Ph.D., University of California, San Diego
- Wesley Cook**, Assistant Professor of Civil Engineering
B.S., New Mexico State University; M.S., Ph.D., Utah State University
- Rodolfo C. Correa**, Deputy Director (EMRTC)
B.S., Western New Mexico University; M.A., Kensington University
- Michelle Creech-Eakman**, Associate Professor of Physics, Chair of the Department; Research Scientist for MROI
B.S., M.S., University of North Dakota; Ph.D., University of Denver
- Gina D'Ambrosio**, Editor (NMBGMR)
B.G.S., New Mexico Institute of Mining and Technology
- Iver Davidson**, Director of Academic Center for Technology
B.A., North Dakota State University; M.F.A., Vermont College; Ph.D., University of Nebraska
- Elaine DeBrine-Howell**, Associate Dean for Student Success
B.A., University of New Mexico; M.A., St. Mary's University
- Valerie DelCurto**, Director of Auxiliary Services
B.B.A., University of New Mexico
- Jessica Dennis**, Coordinator of Human Resources
B.S., M.A., Grand Canyon University
- Mary Dezember**, Professor of English
B.A., University of Evansville; M.A., Ph.D., Indiana University
- Yongtao Dong**, Assistant Professor of Civil Engineering
Ph.D., University of Illinois
- Nelia W. Dunbar**, Analytical Geochemist (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.A., Mount Holyoke College; M.S., Ph.D., New Mexico Institute of Mining and Technology
- Douglas Dunston**, Professor of Music
B.A., M.A., Ph.D., University of New Mexico; M.L.S., Peabody College at Vanderbilt University
- Susan Dunston**, Professor of English
B.A., University of New Mexico; M.A., George Peabody College; M.A., Ph.D., University of New Mexico
- Rosário Durão**, Assistant Professor of Technical Communication
B.A., M.A., University of Lisbon, Portugal; Ph.D., Open University, Portugal
- Andrea Dyjjak**, Counselor for Financial Aid
B.A., Salisbury University
- Ken Eack**, Associate Professor of Physics; Research Physicist
B.S., New Mexico Institute of Mining and Technology; Ph.D., University of Oklahoma
- Taffeta Elliott**, Assistant Professor of Psychology
B.A., St. John's College in Santa Fe; M.Phil, M.A., Ph.D., Columbia University
- Aly I. El-Osery**, Associate Professor of Electrical Engineering
B.S., M.S., Ph.D., University of New Mexico
- Thomas Engler**, P.E., Professor of Petroleum and Chemical Engineering, Research Scientist PRRC)
B.S., M.S., New Mexico Institute of Mining and Technology; Ph.D., University of Oklahoma.
- Hector Erives**, P.E., Associate Professor of Electrical Engineering
B.S., Instituto Tecnológico de Chihuahua; M.S., University of Texas at El Paso; Ph.D., New Mexico State University

- Robert Eveleth**, Senior Mining Engineering (NMBGMR)
B.S., New Mexico Institute of Mining and Technology
- Ahmad Ali Fakhimi**, Professor of Mineral and Mechanical Engineering
B.S., Iran University of Science and Technology; M.S., University of Shiraz, Iran; Ph.D., University of Minnesota
- Tianguang Fan**, Research Chemist (PRRC)
B.S., East China University of Science and Technology M.S., New Mexico Institute of Mining and Technology
- Kathryn Fleming-Gonzales**, Mental Health Counselor for the Office of Counseling and Disability Services (OCDS)
B.S., New Mexico State University; M.S.W., Western New Mexico University
- Julie Dyke Ford**, Professor of English
B.A., Elon University; M.A., University of North Carolina at Charlotte; Ph.D., New Mexico State University
- Joe Franklin**, Director, Information Services
B.S., New Mexico Institute of Mining and Technology
- Bonnie Frey**, Chemistry Laboratory Manager (NMBGMR)
B.A., Goshen College; B.S., University of South Florida at Tampa; M.S., New Mexico Institute of Mining and Technology
- Liliya Frolova**, Associate Research Professor of Chemistry
M.S., Ph.D., V.I. Ulyanov-Lenin State University
- Paul A. Fuierer**, Professor of Materials and Metallurgical Engineering
B.S., Alfred University; Ph.D., Pennsylvania State University
- Leonard Garcia**, Civil Engineer, EMRTC
B.S., Southern Illinois University
- Ashok Ghosh**, P.E., Associate Professor, Mechanical Engineering
B.Tech, Indian Institute of Technology; M.S., Washington State University; Ph.D., Indian Institute of Technology
- Ronnie Grapenthin**, Assistant Professor of Geophysics
M.S., Humboldt-University, Berlin; Ph.D., University of Alaska Fairbanks
- Margaret Griffin**, Instructor of English
B.A., M.A., New Mexico State University; Ph.D., Texas Tech University
- Reid B. Grigg**, Senior Engineer (PRRC); Adjunct Faculty, Petroleum and Chemical Engineering
B.S., Ph.D., Brigham Young University
- Sara Grijalva**, Registrar
B.B.A., Western New Mexico University
- David Grow**, Assistant Professor of Mechanical Engineering
B.S., M.S., University of Utah; Ph.D., Johns Hopkins University
- Camille Gurulé**, Accounting Manager, Business Office
B.G.S., New Mexico Institute of Mining and Technology
- Gloria Gutierrez-Anaya**, Fidel Center Event Specialist and Assistant
B.S., University of Phoenix
- Chris Haniff**, Interferometer System Architect (MRO), Adjunct Faculty, Physics
B.A., Ph.D., University of Cambridge
- Michael Hargather**, Assistant Professor of Mechanical Engineering
B.S., Behrend College; Ph.D., Pennsylvania State University
- James Bruce Jeffers Harrison**, Associate Professor of Environmental Geology; Research Environmental Geologist
B.S., M.S., University of Canterbury, New Zealand; Ph.D., University of New Mexico
- Kent Harvey**, Senior Research Engineer
B.S., New Mexico Institute of Mining and Technology
- Ahmed Hasan**, Senior Research Scientist (IERA)
Ph.D., University of Cairo
- Tristine Hayward**, Assistant Director of Student Affairs
B.S., M.A., New Mexico State University
- Michael D. Heagy**, Professor of Chemistry
B.S., Franklin and Marshall College; Ph.D., University of New Mexico
- Matthew T. Heizler**, Geochronologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.S., University of Minnesota, Duluth; M.S., University of Maine; Ph.D., University of California, Los Angeles
- Jan M.H. Hendrickx**, Professor of Hydrology
B.S., M.S., Agricultural University, Wageningen, The Netherlands; Ph.D., New Mexico State University
- Dale Henneke**, Associate Professor of Materials and Metallurgical Engineering
Ph.D., University of Texas, Austin
- Michael Hensley**, Director, Special Projects, Research and Economic Development
B.S., M.A., Western New Mexico University; Ed.D., Virginia Tech
- Robert Hepler**, Manager of Distance Technologies (ACT)
B.B.A., M.B.A., University of New Mexico
- Steven M. Hicks**, Director of Property Control
A.A., Goldenwest College; B.S., California State University
- Richard Hildebrandt**, Associate Director of Purchasing Services
B.A., California State University
- Heather Himmelberger**, Director of New Mexico Environmental Finance Center, IERA
M.S., Penn State
- Deidre A. Hirschfeld**, Professor of Materials and Metallurgical Engineering
B.S., Carnegie Mellon University; M.A.pp.S., University of British Columbia, Canada; Ph.D., Virginia Polytechnic Institute and State University
- Gretchen Hoffman**, Senior Coal Geologist (NMBGMR)
B.A., Adams State College; M.S., University of Arizona
- Peter Hofner**, Professor of Physics, Adjunct Scientist (NRAO)
M.S., University of Tuebingen, Germany; Ph.D., University of Wisconsin-Madison
- Anwar M. Hossain**, Professor of Mathematics
B.Sc., M.Sc., Jahangirnagar University, Bangladesh; Ph.D., Old Dominion University
- Frank Y. C. Huang**, P.E., Associate Professor of Environmental Engineering; Adjunct Faculty, Petroleum and Chemical Engineering
B.S., National Chung-Hsing University; M.S., Ph.D., Vanderbilt University

- Dennis Hunter**, Associate Director for Safety and Security
- Melissa Jaramillo-Fleming**, Vice President for Student and University Relations; Dean of Students
B.B.A., Eastern New Mexico University; M.S., Grand Canyon University
- Richard Jimenez**, Director, EMRTC
B.S., M.S., California State University, Los Angeles; Ph.D., University of New Mexico
- Peggy Johnson**, Hydrogeologist (NMBGMR)
B.S., Boise State University; M.S., New Mexico Institute of Mining and Technology
- Glen Jones**, Manager, Digital Cartographer Laboratory (NMBGMR)
B.S., New Mexico Institute of Mining and Technology
- Anders Jorgensen**, Associate Professor of Electrical Engineering
B.S., Aarhus University, Denmark; Ph.D., Boston University
- Ronna Kalish**, Program Director, Performing Arts Series
B.S., University of Illinois
- Nikolai Kalugin**, Associate Professor of Materials and Metallurgical Engineering, Chair of the Department
Ph.D., Institute of Applied Physics, the Russian Academy of Science, Nizhny Novgorod, Russia
- Shari Kelley**, Adjunct Faculty, Earth and Environmental Science
B.S., New Mexico State University; Ph.D., Southern Methodist University
- Mike Kelly**, Assistant Professor of Petroleum Engineering
B.S., M.S., Ph.D., New Mexico Institute of Mining and Technology
- Gilbert Kerr**, Assistant Professor of Mathematics
B.Sc., Heriot-Watt; M.S., Ph.D., Old Dominion University
- Janet Kieffer**, Instructor of English
M.A., University of Colorado
- Thomas L. Kieft**, Professor of Biology
B.A., Carleton College; M.S., New Mexico Highlands University; Ph.D., University of New Mexico
- Jamie Kimberley**, Assistant Professor of Mechanical Engineering
B.S., Binghamton University; M.S., Ph.D., University of Illinois at Urbana-Champaign
- Valerie Kimble**, Administrative Assistant/Technical Writer, Academic Affairs
B.S., New Mexico Institute of Mining and Technology
- Kevin L. Kirk**, Associate Professor of Biology
B.S., Oregon State University; M.S., Washington State University; Ph.D., Dartmouth College
- Daniel A. Klingsmith, III**, Adjunct Faculty, Physics
M.S., Ph.D., Indiana University
- Chris Knight**, Network & Client Services Support Tech II, Information Services
B.S., New Mexico Institute of Mining and Technology
- Justin Kombarakkaran**, Instructor of Chemistry
Ph.D., New Mexico Institute of Mining and Technology
- Evelyn Konigsberg**, Banner Technologist
B.S., New Mexico Institute of Mining and Technology; M.S., Montana State University
- Elisabeth Kramer-Simpson**, Assistant Professor of English
B.A., University of Iowa; M.A., University of Wisconsin; Ph.D., University of New Hampshire
- Paul Krehbiel**, Professor of Physics; Senior Research Engineer; Adjunct Faculty, Electrical Engineering
B.S., M.S., Massachusetts Institute of Technology; Ph.D., University of Manchester Institute of Science and Technology, England
- Philip R. Kyle**, Professor of Geochemistry; Geochemist/Petrologist B.Sc., Ph.D., Victoria University of Wellington, New Zealand
- Patricia Landavazo**, Financial System Administrator
B.G.S., New Mexico Institute of Mining and Technology
- Rafael A. Lara-Martinez**, Professor of Foreign Language
Licenciatura in Linguistic Anthropology, Escuela Nacional de Antropología e Historia, México; Diplome d'études Approfondies, Université de La Sorbonne, Paris I
- Robert L. Lee**, Director of the Petroleum Recovery Research Center; Professor of Petroleum and Chemical Engineering
B.S., Chung Yuan Christian College; B.S., M.S., Oregon State University; Ph.D., University of Michigan
- Corey Leclerc**, Associate Professor of Chemical Engineering and Chair of Department
B.S., University of Maine; Ph.D., University of Minnesota
- Nowka Leviner**, Director of Macy Center, Manager of Fidel Student Services Center
B.B.A., University of New Mexico
- Susan Lewark**, CFNP
BSN, University of New Mexico; M.A., Family Nurse Practitioner, University of New Mexico
- Liangxiong Li**, Research Associate (PRRC)
B.S., Hubei University; M.S., Research Institute of Petroleum Exploration and Development; Ph.D., New Mexico Institute of Mining and Technology.
- Lorie M. Liebrock**, Dean of Graduate Studies, Professor of Computer Science and Information Technology, Adjunct Faculty, Management; Research Scientist, ICASA
B.S., M.S., Michigan Technological University; M.S., Ph.D., Rice University
- Seokbin (Bin) Lim**, Associate Professor, Mechanical Engineering
B.S. Chungnam National University, South Korea; M.S.; Ph.D., University of Missouri-Rolla
- Ning Liu**, Research Associate (PRRC)
B.S., M.S., Peking University; Ph.D., New Mexico Institute of Mining and Technology
- Daniel H. López**, President of the Institution; Adjunct Faculty, Humanities
B.A., M.A., Ph.D., University of New Mexico
- Carlos Lopez-Carillo**, Research Physicist, Langmuir Lab
B.S., Autonomous University Of Nuevo Leon, Mexico; Ph.D., New Mexico Institute of Mining and Technology

- John C. Lorenz**, Adjunct Faculty, Petroleum and Chemical Engineering
B.A., Oberlin College; M.Sc., University of South Carolina; Ph.D., Princeton University
- David Love**, Principal Senior Environmental Geologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.S., Beloit College; M.S., Ph.D., University of New Mexico
- Jane Calvert Love**, Managing Editor (NMBGMR)
B.A., B.F.A., M.F.A., University of Nebraska, Lincoln
- Ping Lu**, Professor of Materials and Metallurgical Engineering
B.S., Nanjing University, China; Ph.D., Arizona State University
- Virgil W. Leuth**, Mineralogist (NMBGMR)
B.S., University of Wisconsin at Eau Claire; M.S., Ph.D. University of Texas at El Paso
- Dan Luncford**, Manager of Networking Services, Information Services
B.S., New Mexico Institute of Mining and Technology
- Patience Lyman**, Assistant Registrar
B.S., New Mexico Institute of Mining and Technology
- Shaojie (Jenny) Ma**, Database Programmer and Administrator (PRRC)
B.S., Liaoning University, China; M.S., New Mexico State University
- Bhasker S. Majumdar**, Professor of Materials and Metallurgical Engineering
B.Tech, IIT Kanpur, India; ME, IISc Bangalore India; Ph.D., University of Rochester, NY
- Kierran Maher**, Assistant Professor of Economic Geology
B.S., Brigham Young University; M.S., Ph.D., Washington State University
- Oleg Makhnin**, Associate Professor of Mathematics
B.S., M.S., Novosibirsk University; Ph.D., Michigan State University
- Yvonne Manzano**, Director, Facilities Management
B.A., New Mexico State University
- Michael Maroun**, Visiting Assistant Professor of Mathematics
B.S., University of Texas; M.S., University of Florida; Ph.D., University of California Riverside
- Lonnie Marquez**, Vice President for Administration and Finance
B.A., New Mexico Highlands University
- Subhasish Mazumdar**, Associate Professor of Computer Science and Information Technology; Adjunct Faculty, Management
B.Tech., Indian Institute of Technology, Kharagpur, M.E., Indian Institute of Science, Bangalore; M.S., Ph.D., University of Massachusetts at Amherst
- John McCoy**, Professor of Materials and Metallurgical Engineering
B.A., Bucknell University; M.S., Ph.D., University of Pennsylvania
- William C. McIntosh**, Volcanologist/ Geochronologist (NMBGMR); Associate Professor Geochemistry
A.B., Princeton University; M.S., University of Colorado; Ph.D., New Mexico Institute of Mining and Technology
- Anna McLain**, Director of Sponsored Projects, Business Office
B.B.A., University of New Mexico
- James McLain**, Director of Special Projects, Business and Finance
B.B.A., University of New Mexico
- Kelly McLain**, Research Engineer, EMRTC
B.S., New Mexico Institute of Mining and Technology
- Virginia McLemore**, Senior Economic Geologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science and Mineral Engineering
B.S., New Mexico Institute of Mining and Technology; Ph.D., University of Texas at El Paso
- David Meier**, Associate Professor of Physics
B.A., California State University Los Angeles; M.S., Ph.D., University of California Los Angeles
- Jason Metzger**, Research Engineer, EMRTC
B.S., University of New Mexico; M.S., New Mexico Institute of Mining and Technology
- A. Keith Miller**, Associate Professor of Mechanical Engineering
B.S., M.S., Ph.D., University of Wyoming
- Kimela Miller**, Chief Procurement Officer of Purchasing Services
B.B.A., M.B.A., New Mexico State University
- Kenneth R. Minschwaner**, Professor of Physics; Research Physicist
B.S., M.S., Florida Atlantic University; Ph.D., Harvard University
- Navid Mojtabai**, Professor of Mineral Engineering, Chair of the Department
B.S., M.S., New Mexico Institute of Mining and Technology; Ph.D., University of Arizona
- Marliss Monette**, Director of Financial Aid
B.B.A., New Mexico State University
- Rachel Montoya**, Manager of Classroom Technology for the Academic Center for Technology (ACT)
B.F.A., New Mexico Highlands University
- Russell Moore**, Director of Golf, P.G.A.
B.A., New Mexico Highland University
- Stephany Moore**, Institutional Researcher
B.S., New Mexico Institute of Mining and Technology
- Raul Morales Juberias**, Associate Professor Physics
B.S., University of La Laguna, Tenerife; Ph.D., University of Basque Country, Vizcaya
- Dennis Morrison**, Director (IERA)
Ph.D., University of New Mexico
- Arash Mousavi**, Assistant Professor of Mechanical Engineering
Ph.D., University of New Mexico
- Peter S. Mozley**, Professor of Geology
A.B., Oberlin College; M.S., University of Colorado; Ph.D., University of California, Santa Barbara
- Srinvas Mukkamala**, Adjunct Faculty, Computer Science
M.S., Ph.D., New Mexico Institute of Mining and Technology
- Mark Murray**, Associate Research Professor of Geophysics
B.S., Ph.D., Massachusetts Institute of Technology
- Julianne Newmark**, Associate Professor of English
B.A., University of Michigan; M.A., Ph.D., Wayne State University

- Tan C. Nguyen**, Assistant Professor of Petroleum Engineering
B.S., M.S., Ho Chi Minh Technology University; Ph.D.,
University of Tulsa
- Anthony Ortiz**, Director, Office of Admission
B.A., College Santa Fe
- Warren Ostergren**, Vice President for Academic Affairs; Associate
Professor of Mechanical Engineering and Management
B.S., University of Rochester; M.S., Brown University;
Ph.D., Rensselaer Polytechnic Institute
- Mark Person**, Professor of Hydrology
B.A., Franklin & Marshall College; M.S., New Mexico Institute
of Mining and Technology; Ph.D., Johns Hopkins University
- Lisa Peters**, Geological Lab Associate (NMBGMR)
B.S., University of Wisconsin, Eau Claire; M.S., University of
Texas, El Paso
- W. Dennis Peterson**, Special Assistant to the President; Director
(ICASA); Adjunct Faculty, Information Technology
B.S., University of Utah
- Fred M. Phillips**, Professor of Hydrology; Research Hydrologist
B.A., University of California, Santa Cruz; M.S., Ph.D.,
University of Arizona
- Menake Piyasena**, Assistant Professor of Chemistry
B.S., University of Kelaniya; Ph.D., University of New Mexico
- Sally Pias** Assistant Professor of Chemistry
B.A., M.A., Emory University; Ph.D., New Mexico State
University
- Max Planck**, Systems Engineer, ICASA
B.S., New Mexico Institute of Mining and Technology
- L. Greer Price**, Senior Geologist, Chief Editor (NMBGMR)
B.A., M.A., Washington University, St. Louis
- Alexander V. Prusin**, Professor of History
B.A., M.A., University of Wisconsin-Milwaukee; Ph.D.,
University of Toronto
- Hamid Rahnama**, Assistant Professor of Petroleum Engineering
B.S., Petroleum University of Technology; M.S., French
Institute of Petroleum; Ph.D., Texas A&M University
- Mahinda Ranasinghe**, Assistant Professor of Chemistry
B.S., University of Peradeniya, Sri Lanka; Ph.D., Wayne State
University
- Geoffrey Rawling**, Field Geologist (NMBGMR)
B.S., Penn State University; M.S. SUNY at Stony Brook;
Ph. D., New Mexico Institute of Mining and Technology
- David J. Raymond**, Professor of Physics; Research Physicist
B.S., Rensselaer Polytechnic Institute; Ph.D., Stanford University
- Mehrdad Razavi**, Associate Professor of Mineral Engineering
B.S., Shiraz University, Iran, M.S., Shiraz University, Iran; Ph.D.,
Washington State University.
- Adam S. Read**, Geologist/Webmaster (NMBGMR)
B.S., M.S., University of New Mexico
- Frank Reinow**, Assistant Professor of Management; Chair of the
Department
B.A., Park College; M.G.A., University of Pennsylvania;
Ph.D., University Southern California
- Rebecca A. Reiss**, Associate Professor of Biology
B.S., University of Colorado; M.S., University of New
Hampshire; Ph.D., Cornell University
- David Reusch**, Associate Research Professor of Climatology
B.A., University of Maine; M.S., University of New Hampshire;
Ph.D., Pennsylvania State University
- Abdelmounaam Rezgui**, Assistant Professor of Computer Science
and Information Technology
Ph.D., Virginia Tech
- Clinton P. Richardson**, P.E, Professor of Environmental
Engineering, Chair of the Department
B.S., Western Kentucky University; M.S., University of Texas
At Austin; Ph.D. University of Kansas
- William Rison**, Professor of Electrical Engineering; Adjunct
Faculty, Physics
B.S., University of Wyoming; M.A., Ph.D., University of
California at Berkley
- Snezna Rogelj**, Professor of Biology, Chair of the Department
B.S., Ohio State University; Ph.D., Boston University School of
Medicine
- Van Romero**, Vice President for Research and Economic
Development; Professor of Physics
B.S., M.S., New Mexico Institute of Mining and Technology;
Ph.D., State University of New York at Albany
- Roland Rowe**, Instructor of English
M.A., University of New Mexico
- Tongjun “Roger” Ruan**, Research Scientist (PRRC), Adjunct
Faculty, Petroleum Engineering
B.S., M.S., Shandong University of Technology, Jinan, China;
Ph.D., China University of Geosciences, Beijing, China
- Gayan Rubasinghe**, Assistant Professor of Chemistry
B.S., University of Kelaniya; Ph.D., University of Iowa
- Eileen Ryan**, Adjunct Faculty, Physics
B.S., Rutgers University; M.S., New Mexico State University;
Ph.D., University of Arizona
- Donghyeon Ryu**, Assistant Professor of Mechanical Engineering
B.S., M.S., Yonsei University, South Korea; M.S., Ph.D.,
University of California, Davis
- Barry Sabol**, Physics Lab Associate
B.S., M.S., New Mexico Institute of Mining and Technology
- JoAnn Salome**, Director of Human Resources
B.S., M.S., New Mexico State University
- Mark Samuels**, Associate Professor of Psychology, Chair of the
Department
B.A., State University of New York at Albany; M.A., University
of Chicago; Ph.D., New York University
- Barbara Sanchez**, Analyst II-Federal Compliance, Budget & Analysis
B.G.S., New Mexico Institute of Mining and Technology
- Cecilia Sanchez**, Manager of Internal Control, Business Office
A.G.S., New Mexico Institute of Mining and Technology
- Ramon Russell Sanchez**, Assistant Director of Macey and Fidel
Center
B.S., New Mexico State University

- Steve Schaffer**, Associate Professor of Mathematics; Research Scientist, ICASA
B.S., California at Berkeley; Ph.D., Colorado State University
- Peter A. Scholle**, Director of the Mexico Bureau of Geology and Mineral Resources and State Geologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.S., Yale University; M.A., Ph.D., Princeton University
- Leyla Sedillo**, Associate Vice President for Budget
B.S., New Mexico Institute of Mining and Technology
- Seda Senay**, Assistant Professor of Electrical Engineering
B.S., M.S., Yeditepe University, Istanbul; Ph.D., University of Pittsburgh
- Randall S. Seright**, Senior Engineer and Associate Director (PRRC); Adjunct Faculty, Petroleum and Chemical Engineering
B.S., Montana State University; Ph.D., University of Wisconsin-Madison
- Sharon Sessions**, Associate Professor of Physics
B.S., New Mexico Institute of Mining and Technology; M.S., Ph.D., University of Oregon
- Dongwan Shin**, Associate Professor of Computer Science and Information Technology; Chair of the Department
B.A., Hongik University; M.S., Ph.D., University of North Carolina at Charlotte
- Steve Simpson**, Associate Professor of Communication; Chair of the Department
M.A., University of Cincinnati; Ph.D., University of New Hampshire
- Hamdy S. Soliman**, Professor of Computer Science and Information Technology
B.S., Alexandria University; M.S., Florida Institute of Technology; Ph.D., New Mexico State University
- Richard Sonnefeld**, Professor of Physics
B.S.E., Princeton University; Ph.D., University of California, Santa Barbara
- Glenn Spinelli**, Associate Professor of Geophysics
B.S., Pennsylvania State University; Ph.D., University of California
- Michael Stanley**, Associate Director of Applied Research and Technology, EMRTC
B.S., New Mexico Institute of Mining and Technology
- John Starrett**, Associate Professor of Mathematics
B.S., Metropolitan State College of Denver; M.S., Ph.D., University of Colorado at Denver
- Glenda Stewart-Langley**, Instructor in Humanities
B.S., Northern State College, Aberdeen, SD; M.A., Texas A & M University, Kingsville, TX
- Edie Steinhoff**, Graphic Designer, Office of Advancement
A.A., Francis Marion University; B.F.A., Texas Women's University; M.A., American International University
- William Dean Stone**, Professor of Mathematics; Dean of Arts & Sciences; Research Scientist, ICASA
B.S., M.A., Ph.D., University of Utah
- Toshiyuki Sueyoshi**, Professor of Management; Adjunct Faculty, Information Technology
B. Eng., Ishikawa Technical College; B.Eng., Nagoya Institute of Technology; M.Eng. Tokyo Institute of Technology; Ph.D., University of Texas at Austin
- William Tafoya**, Research Engineering II (EMRTC)
B.S., New Mexico Institute of Mining and Technology
- Michaelann Tartis**, Associate Professor of Chemical Engineering
B.S., New Mexico Institute of Mining and Technology; Ph.D., University of California Davis
- Scott W. Teare**, Professor of Electrical Engineering; Adjunct Faculty, Physics
B.Sc., M.Sc., Ph.D., University of Guelph, Ontario, Canada
- Rodolfo Tello-Aburto**, Assistant Professor of Chemistry
B.S., Universidad Veracruzana; M.S., Universidad Nacional Autonoma de Mexico; Ph.D., University of Iowa
- Mary E. Templeton**, Staff Scientist (IRIS)
B.A., San Francisco State University; M.A., University of California, Berkeley; Ph.D., University of Wyoming
- Ronald J. Thomas**, Professor of Electrical Engineering and Adjunct Faculty, Physics
B.S., New Mexico State University; M.S., Ph.D., Utah State University.
- Stewart Thompson**, Assistant Professor of Psychology
Ph.D., Imperial College London
- Alex K. Thyssen**, Internal Auditor; Executive Secretary New Mexico Tech Research Foundation
- J. Michael Timmons**, Geologic Mapping Program Manager, Field Geologist, (NMBGMR)
B.S., University of Nebraska, M.S., Ph.D., University of New Mexico
- Millie Tourville**, Payroll Manager, Business Office
B.GS., New Mexico Institute of Mining and Technology
- Melissa Tull**, Controller
B.B.A., New Mexico Institute of Mining and Technology; M.B.A., University of Phoenix
- Dana Ulmer-Scholle**, Adjunct Faculty, Earth & Environmental Science
B.S., University of Cincinnati; Ph.D., Southern Methodist University
- Arleen Valles**, Director of Finance, Business Office
B.A., M.B.A., New Mexico Highlands University
- Michael Voegerl**, Director of Student Affairs
B.S., University of Southern Indiana
- Daniel C. Walsh**, Associate Vice President of Research & Economic Development
B.S., M.A., Northwestern State University; Ed.D., Louisiana State University
- Bixiang Wang**, Professor of Mathematics
B.S., M.S., Ph.D., Lanzhou University, China; M.S., University of McMaster, Canada

Janet Ward, Director of the Office of Counseling and Disability Services (OCDS)
B.S.W., Indiana State University; M.S.W., Widener University

Kevin J. Wedeward, Professor of Electrical Engineering and Information Technology, Chair of the Department; Dean of Engineering; Research Scientist and Chief Scientist, ICASA
B.S., Ph.D., New Mexico State University

Tie Wei, Assistant Professor of Mechanical Engineering
B.S., Shanghai Jiaotong University, China; Ph.D., University of Utah

Susan J. Welch, Manager, Geologic Extension Service (NMBGMR)
B.S., New Mexico State University

David J. Westpfahl, Professor of Astrophysics
B.S., Dartmouth College; M.S., Yale University; Ph.D., Montana State University

David A. Wheelock, Coordinator of Club Sports and Rugby
B.A., University of New Mexico

Bryon J. Whitehorse, Manager of Property Control
B.G.S., B.S., New Mexico Institute of Mining and Technology;

Jolante Van Wijk, Assistant Professor of Geophysics
Ph.D., Vrije Universiteit, Amsterdam The Netherlands

Maureen Wilks, Geological Librarian, Manager Information Center (NMBGMR)
B.A., Oxford University, Great Britain; M.Sc., University of Saskatchewan, Canada; Ph.D., New Mexico Institute of Mining and Technology

Claudia M.D., Wilson, Associate Professor of Civil Engineering
B.S., M.S., Ph.D., Florida State University

John L. Wilson, Professor of Hydrology; Senior Research Hydrologist
B.C.E., Georgia Institute of Technology; S.M., C.E., Ph.D., Massachusetts Institute of Technology

Oliver Wingenter, Associate Professor of Chemistry
B.S., San Jose State University; Ph.D., University of California, Irvine

Nadir Yilmaz, Associate Professor of Mechanical Engineering
B.S., Istanbul Technical University; M.S., Bradley University; Ph.D., New Mexico State University

Lisa Young, Professor of Physics
B.A., Harvard University, Ph.D., University of Illinois at Urbana

Yan Yuan, Assistant Professor of Management
Ph.D. New York State University Stony Brook

Andrei Zagrai, Associate Professor of Mechanical Engineering, Chair of the Department
B.E., M.E., Taganrog State University of Radio-Engineering in Russia; Ph.D., University of South Carolina.

Luzheng “Frank” Zhang, Research Scientist (PRRC)
B.S., Anhui University of Technology; M.S., Nanjing University of Chemical Technology; Ph.D., Kansas State University

Jun Zheng, Associate Professor of Computer Science and Information Technology
Ph.D., University of Nevada

Tony Zimmererly, Research Engineering (EMRTC)
B.S., M.S., New Mexico Institute of Mining and Technology

Emeritus

Joyce M. Aguilar, Registrar Emerita
A.G.S. New Mexico Institute of Mining and Technology

Catherine T. Aimone-Martín, Professor Emerita of Mineral Engineering
B.S., Michigan Technological University; Ph.D., Northwestern University

David R. Arterburn, Associate Professor Emeritus of Mathematics,
B.S., Southern Methodist University; M.S., Ph.D., New Mexico State University

George S. Austin, Senior Industrial Mineral Geological Emeritus (NMBGMR); Adjunct Faculty, Earth and Environmental Science
B.A., Carleton College; M.S., University of Minnesota; Ph.D., University of Iowa

James M. Barker, Section Head, Publications and Senior Emeritus Industrial Minerals Geologist (NMBGMR); Adjunct Faculty, Earth and Environmental Science and Mineral Engineering
B.S., University of California, Los Angeles; M.A., University of California, Santa Barbara

Gillian Bond, Professor Emerita of Materials and Metallurgical Engineering
Ph.D., Bath University, United Kingdom

Robert H. Bond, Professor Emeritus of Electrical Engineering
B.S.E.E., Colorado State University, M.S., Ph.D., California Institute of Technology

Donald K. Brandvold, Professor Emeritus of Chemistry
B.S., Ph.D., North Dakota State University

Lynn A. Brandvold, Senior Chemist Emerita (NMBGMR)
B.S., M.S., North Dakota State University

Robert Bretz, Professor Emeritus of Chemical Engineering
B.S., M.S., Ph.D., Texas A&M

Kay R. Brower, Professor Emerita of Chemistry
B.S., Massachusetts Institute of Technology; M.S., University of Maine, Ph.D., Lehigh University

Antonius J. Budding, Professor Emeritus of Geology
B.Sc., M.Sc., Ph.D., University of Amsterdam, Netherlands

Andrew Campbell, Professor Emeritus of Geology
B.S., Oregon State University; M.S., Ph.D., Harvard University

Charles P. Campbell, Professor Emeritus of English
B.A., M.A., University of Colorado, Boulder; Ph.D., University of New Mexico

Charles Edward Chapin, Director Emeritus of New Mexico Bureau of Geology and Mineral Resources (NMBGMR)
B.S., D.Sc., Colorado School of Mines

Paige W. Christiansen, Professor Emeritus of History
B.A., Michigan State University; M.A., University of New Mexico; Ph.D., University of California at Berkeley

James Corey, Professor Emeritus of English
B.S., Montana State University; M.A., University of Montana; Ph.D., Washington State University

Robert H. Cormack, Professor Emeritus of Psychology
A.B., M.A., Ph.D., University of Cincinnati

- Lynn Deming**, Professor Emerita of English
B.A., University of Colorado, Boulder, M.A., Ph.D.,
University of Oklahoma, Norman
- Jean A. Eilek**, Professor Emerita of Astrophysics; Research
Astrophysicist
B.A., University of California at Berkeley; Ph.D., University of
Iowa
- Frank Etscorn**, Professor Emeritus of Psychology
B.A., M.A., Western Kentucky University; Ph.D., Vanderbilt and
George Peabody College in Nashville
- Gerado W. Gross**, Professor Emeritus of Geophysics; Senior
Research Geophysicist Emeritus
Sc.D, University of Cordoba, Argentina; Ph.D., Pennsylvania
State University
- Ruth L. Gross**, Professor Emerita of Foreign Languages
BA., Instituto Nacional del Profesorado en Lenguas Vivas,
London, United Kingdom; Ph.D., University of New Mexico
- Timothy H. Hankins**, Professor Emeritus of Physics
(Astrophysics)
A.B., M.S., Dartmouth College; Ph.D., University of California at
San Diego
- Melvin J. Hatch**, Professor Emeritus of Chemistry
B.S., University of Arizona; Ph.D., University of California
At Los Angeles
- John W. Hawley**, Senior Environmental Geologist Emeritus;
Adjunct Faculty, Earth and Environmental Science
B.A., Hanover College; Ph.D., University of Illinois at Urbana
- Robert Holson**, Professor Emeritus of Psychology
B.A., University of California at Berkeley; Ph.D., University of
Washington
- David B. Johnson**, Professor Emeritus of Geology
B.S., Oregon State University; M.A., Ph.D. University of Iowa
- Laurence H. Lattman**, President Emeritus of the Institute and
Professor Emeritus of Geology and Geophysics
B.Ch.E., City of College New York; M.S., Ph.D., University of
Cincinnati
- Vernon G. LeFebvre**, Associate Professor Emeritus of Physics
B.S., Purdue University; Ph.D., University of Utah
- Virginia Marquez**, Registrar Emeritus
- John P. McLain**, Director Emeritus of TERA
B.S., University of Arizona
- John L. Meason**, Emeritus Adjunct Faculty, Physics and Electrical
Engineering
B.S., West Texas A & M University; M.S., Ph.D., University of
Arkansas
- Alan R. Miller**, Professor Emeritus of Engineering
B.S., M.S., Ph.D., University of California at Berkeley
- Robert Neil**, Director Emeritus of Environmental Evaluation
Group
B.A., Stevens Institute of Technology; M.S., Harvard University
- Gary Olsen**, Professor Emeritus of History
B.A., Washington State University; M.A., Ph.D., University
Of Arizona
- Kalman I Oravec**, P.E., Professor Emeritus of Mineral Engineering
B.Sc., M.Sc., University of Durham, United Kingdom; Ph.D.,
University of Witwatersrand, South Africa
- Carl J. Popp**, Professor Emeritus of Chemistry
B.S., Colorado State University; M.A., Southern Illinois
University; Ph.D., University of Utah
- Betty B. Reynolds**, Library Director Emerita
B.A., Northern Illinois University; M.A., University of Denver;
M.B.A., University of Missouri-Kansas City
- Allan R. Sanford**, Professor Emeritus Geophysics; Senior Research
Geophysicists
B.A., Pomona College; M.S., Ph.D., California Institute of
Technology
- Stephen D. Schery**, Professor Emeritus of Physics; Research
Physicist
B.S., Ohio State University; M.S., University of Arkansas; Ph.D.,
University of Colorado
- John Schlue**, Associate Professor Emeritus of Geophysics; Research
Geophysicist Emeritus
B.A., M.S., Ph.D., University of California at Los Angeles
- Alan Sharples**, Professor Emeritus of Mathematics
B.Sc., Ph.D., University of Manchester, United Kingdom
- David K. Shortess**, Professor Emeritus of Biology
B.A., Lycoming College; M.Ed., Ph.D., Pennsylvania State
University
- James A. Smoke**, Professor Emeritus of Biology
B.S., Jacksonville State University; M.S., Ph.D., University
of Tennessee
- Allan M. Stavelly**, Associate Professor Emeritus of Computer Science
B.S.E., M.A., Ph.D., University of Michigan
- Joseph J. Taber**, Director Emeritus of Petroleum Recovery Research
Center; Adjunct Faculty, Petroleum and Chemical Engineering
B.S., Muskingum College; Ph.D., University of Pittsburgh
- Samuel Thompson III**, Senior Petroleum Geologist Emeritus
B.S., Southern Methodist Univ.; M.S., Univ. of New Mexico
- Spencer Wilson**, Professor Emeritus of History
B.A., M.A., University of New Mexico; Ph.D., University of
Maryland
- Jan K. Wolski**, Professor Emeritus of Mineral Engineering
M.Sc., Ph.D., Silesia Technical University, Poland

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