College of Engineering and Physical Sciences

www.ceps.unh.edu

Joseph C. Klewicki, Dean
Robert M. Henry, Associate Dean
Janet W. Campbell, Associate Dean

Department of Chemical Engineering
Department of Chemistry
Department of Civil Engineering
Department of Computer Science
Department of Earth Sciences
Department of Electrical and Computer Engineering
Department of Mathematics and Statistics
Department of Mechanical Engineering
Department of Physics

Bachelor of Science
Chemical Engineering*
- Bioengineering
- Energy
- Environmental Engineering

Chemistry*
Civil Engineering*
- International Affairs (dual major)

Computer Engineering*
Computer Science*
- Bioformatics

Electrical Engineering*
Environmental Engineering*†
- Industrial Process
- Municipal Process

Environmental Sciences*
- Ecosystems
- Hydrology
- Soil and Watershed Management

Geology*
Information Technology
Mathematics*
Mathematics Education*
- Elementary
- Middle/Junior High
- Secondary

Mathematics, Interdisciplinary
- Computer Science
- Economics
- Electrical Science
- Physics
- Statistics

Mechanical Engineering*
Physics*
- Astronomy
- Chemical Physics
- Materials Science

Bachelor of Arts
Chemistry
Chemistry and Physics Teaching
Earth Science Teaching
Earth Sciences
- Oceanography

Mathematics
Physics

*Designated degree (the name of the specialization is on the diploma, e.g., B.S. in chemistry).

†Multidisciplinary; i.e., offered in collaboration with two departments.

The College of Engineering and Physical Sciences provides an opportunity for students to achieve educational objectives appropriate to their interests in engineering, computer science, mathematics, the physical sciences, and the teaching of mathematics and physical sciences. The college offers an education in each of its primary disciplines leading to the bachelor of science, as well as bachelor of art degrees with majors in mathematics and each of the three physical sciences. All programs include an opportunity for study in the arts, humanities, and social sciences.

The key to an undergraduate program in the college is flexibility, with a strong emphasis on personal and individualized education. In addition to specific programs, a wide range of options is available. Special programs can be developed to meet the specific interests of individual students.

Degree Requirement

MATH 425 and 426 (Calculus I and II) or the equivalent in transfer credits or advanced placement approved by the Department of Mathematics and Statistics are required by all departments of the college (except Information Technology major). The prerequisites for calculus are three years of college-preparatory mathematics, including a half-year of trigonometry. Before students can register for MATH 425, they are required to take the Mathematics Placement Test.

Mathematics Placement

First-year students arrive with a wide range of mathematical skills based on high school preparation. The college wants students to have a solid mathematics foundation so that they will enjoy an enriched first-semester experience. Mathematics development will be assessed during June orientation and students will be enrolled in the class that will allow them to continue that development. The initial entry course is Analysis and Applications of Functions (MATH 418). However, a placement evaluation will be given to allow a student to place out of MATH 418 into MATH 425 (Calculus I). Students with AP credit for Calculus I and/or Calculus II may elect to accept those credits and continue with a math course at the next level.

Accreditation

The baccalaureate-level programs in chemical, civil, computer, electrical, environmental, and mechanical engineering are accredited by the Engineering Accreditation Commission of ABET, Inc. The baccalaureate-level program in computer science is accredited by the Computing Accreditation Commission of ABET, Inc. ABET contact information: 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700. The Department of Chemistry's undergraduate bachelor of science program is approved by the American Chemical Society.

Tech Courses

The following courses are designed for students of the college and for other majors within the University. These courses are offered through and administered by the Dean's Office.

TECH 400, Introduction to CEPS Programs, 1 cr.
TECH 444, Symmetry in Nature, The Arts, and Daily Life, 4 cr.
TECH 564, Fundamentals of CAD, 3 cr.
TECH 583, Technology: Cultural Aspects, 4 cr.
TECH 583H, Honors/Technology: Cultural Aspects, 4 cr.
TECH 601, Fundamentals Examination Review Course, 1 cr.
TECH 685, Budapest Program, 20 cr.
TECH 696, Independent Study, 1 to 4 cr.
TECH 797, Undergraduate Ocean Research Project, 2 cr.

Degrees

Bachelor of Arts

Programs leading to a bachelor of arts degree are offered in the departments of chemistry, earth sciences, mathematics, and physics. These programs provide a broad liberal education along with a major in one of these fields. See University Academic Requirements, page 18, for requirements for the bachelor of arts degree.

Bachelor of Science

The programs leading to the bachelor of science degree, offered in each of the departments of the college, emphasize students' preparation for a professional career and continuing or graduate education.

The degree requirements for the bachelor of science include the University general education requirements and the specific departmental requirements for graduation. A minimum grade-point average of 2.0 must

be achieved. Graduation credit requirements established by the departments range from 128 to 134. There are entrance requirements in some programs, and it is not possible to guarantee all change-of-major requests.

Interdisciplinary Programs

Majors

Bachelor of Science in Environmental Engineering

The environmental engineering program consists of two emphases: industrial processes (IP) and municipal processes (MP). See page 70.

Bachelor of Science in Environmental Sciences

The environmental sciences program is offered jointly with the College of Life Sciences and Agriculture and consists of three options: hydrology, soil and watershed management, and ecosystems. See page 67.

Minors

Interdisciplinary minors enable students to obtain experience in a specialized area and to retain identification with their major professional area. The college's interdisciplinary minors are:

Applied mathematics, page 74
Environmental engineering, page 72
Geology, page 67
Information technology, page 65
Materials science, page 76
Mathematics, page 74
Mechanical engineering, page 76
Ocean engineering, page 117
Oceanography, page 66
Physics, page 73
Statistics, page 74

For requirements regarding minors, see University Academic Requirements, page 16.

Other Programs

Independent Study and Projects

All departments within the college offer independent study and/or projects. The content of these courses varies based upon current scientific and technological needs and student and faculty interest.

Permission of the instructor and/or department chairperson is required. (See the course descriptions for the independent study and project courses and for specific requirements.) Students interested in working with a faculty member on a project or independent study should discuss this with their academic adviser.

Research Opportunities

The talents and expertise of the faculty in all departments are reflected in the number of ongoing research projects. Undergraduates are included in many of these research projects with the intent that they discover and foster their creative talents. In funded research projects, students may have an opportunity to receive pay while learning.

The college has world-class laboratories and computer facilities in the areas of coastal and ocean mapping, space science, environmental engineering and science, fluid dynamics, information systems, materials science, nanotechnology, sustainable energy, and medical imaging. These and other ongoing research areas within the college are described on the college's website: www.ceps.unh.edu/research.

Students have the opportunity to acquire applied experience by working with faculty members who undertake client-sponsored professional projects in technical and managerial areas for business and industry and for federal, state, and local governments.

Special Provisions

The requirement of a given course in any prescribed curriculum may be waived by the faculty of a student's college. This rule offers students the opportunity to develop a somewhat individualized plan of study with intellectual incentives and opportunities in addition to those in a regular curriculum. The student's petition must be approved by his/her major adviser and the dean of the college. This power usually will be delegated by the faculty to the dean or to a committee. (Senate Rule 05.21(s): Waiver of Requirements in a Prescribed Curriculum.)

A student with senior status and a grade point average of 3.2 may petition to take a graduate course for undergraduate credit. In addition, upon the recommendation of the department chairperson, a superior student may be allowed to count credits from up to two 800-level courses toward both a bachelor's degree and a master's degree, provided that the student has been admitted to the master's program.

Study Abroad Programs

Hungary

The College of Engineering and Physical Sciences provides its students with the opportunity to spend the fall semester of their junior year at the Budapest University of Technology and Economics (BME) in Budapest, Hungary. Courses at BME are taught in English and receive prior approval for degree credit. Students studying in Budapest maintain their status as UNH students, pay UNH tuition, and will be able to graduate from UNH on schedule. A general education course on the language, geography, and culture of Hungary, taken at BME, is strongly suggested. The foreign student office at BME appoints a Hungarian adviser for each student and assists students in obtaining housing either in dormitories or apartments. For more information, visit the program's Web site at www.ceps.unh.edu/academics/budapest/.

Scotland, Heriot-Watt University Exchange Program

College of Engineering and Physical Sciences students are eligible to participate in a spring semester exchange with Heriot-Watt University in Edinburgh, Scotland. The current program is designed for civil and environmental engineering majors. For more information, contact Ray Cook at (603) 862-1411 or the Center for International Education, Hood House.

Preparing for Teaching

Students interested in mathematics education (elementary, middle/junior high, or secondary), chemistry and physics teaching, Earth science teaching, or general science teaching should refer to the appropriate department for a description of the program requirements.

Combined Programs of Study

In addition to pursuing a single major, students may combine programs of study as follows:

Minors: See University Academic Requirements, page 19; see also Degrees and Major Programs of Study and Departmental Programs of Study.

Second majors: See University Academic Requirements, page 19.

Interdisciplinary majors: Many departments in the college offer programs that combine a major with another field of interest. See the descriptions that follow.

Dual-degree programs: See University Academic Requirements, page 18.

Student-designed majors: See Special University Programs, page 119.

Other combined and interdisciplinary opportunities: See Special University Programs, page 114.

Programs of Study

In addition to the following departmental majors and options, departmental minors are offered in chemical engineering, chemistry, electrical engineering, geology, hydrology, mathematics, applied mathematics, mechanical engineering, physics, and statistics.

Chemical Engineering (CHE)

www.unh.edu/chemical-engineering/

(For course descriptions, see page 165.)

Chairperson: Palligarnai T. Vasudevan

Professor: Dale P. Barkey, Russell T. Carr, Ihab H. Farag, Virendra K. Mathur, Palligarnai T. Vasudevan

Associate Professor: Nivedita R. Gupta

Assistant Professor: Xiaowei Teng

The Department of Chemical Engineering currently offers the undergraduate degree program in chemical engineering with options in bioengineering, energy, and environmental engineering. In addition, the College of Engineering and Physical Sciences offers an interdisciplinary B.S. program in environmental engineering with the participation of the chemical engineering and civil engineering departments.

The B.S. program in chemical engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

Chemical engineering is concerned with the analysis and design of processes that deal with the transfer and transformation of energy and material.

The practice of chemical engineering includes the conception, development, design, and application of physicochemical processes and their products; the development, design, construction, operation, control, and management of plants for these processes; and activities relating to public service, education, and research.

The curriculum prepares students for productive careers in industry or government and provides a foundation for graduate studies. The college's program emphasizes chemical engineering fundamentals while offering opportunities for focused study in energy, environmental, or bioengineering.

Traditional employment areas in the chemical process industries include industrial chemicals, petroleum and petrochemicals, plastics, pharmaceuticals, metals, textiles, and food. Chemical engineers are also working in increasing numbers in the areas of energy engineering, pollution abatement, and biochemical and biomedical engineering; in addition, they are employed by many government laboratories and agencies as well as private industries and institutions.

Mission

The College of Engineering and Physical Sciences strives to prepare students for productive careers in industry or government as well as to provide a foundation for graduate studies. The college's program emphasizes chemical engineering fundamentals while offering opportunities for focused study in energy-, environmental-, or bioengineering.

Educational Objectives

The chemical engineering program seeks to provide an environment that enables students to pursue their goals in an innovative program with a diversity of offerings that is rigorous and challenging.

The program has the following major educational objectives with the expectation that graduates will have successful careers in the many diverse areas of the chemical engineering profession.

Depth: An understanding of the fundamental knowledge prerequisite for the practice of, or for advanced study in, chemical engineering, including its scientific principles, analysis, and design.

Breadth: A broad education, including knowledge of important current issues in engineering (with emphasis on the many diverse areas in chemical engineering), necessary for productive careers in the public or private sectors, or for the pursuit of graduate education.

Professionalism: Skills for clear communication and responsible teamwork, professional attitude and ethics that prepare graduates for the complex modern work environment and for lifelong learning.

Bachelor of Science in Chemical Engineering

Chemical engineering is concerned with the analysis and design of processes that deal with the transfer and transformation of energy and material.

The practice of chemical engineering includes the conception, development, design, and application of physicochemical processes and their products; the development, design, construction, operation, control, and management of plants for these processes; and activities relating to public service, education, and research.

The curriculum prepares students for productive careers in industry or government and provides a foundation for graduate studies. The program emphasizes chemical engineering fundamentals while offering opportunities for focused study in energy-, environmental-, or bioengineering.

Traditional employment areas in the chemical process industries include industrial chemicals, petroleum and petrochemicals, plastics, pharmaceuticals, metals, textiles, and food. Chemical engineers also are working in increasing numbers in the areas of energy engineering, pollution abatement, and biochemical and biomedical engineering; in addition, they are employed by many government laboratories and agencies as well as private industries and institutions.

Graduates from the program have the ability to apply knowledge of mathematics, science, and engineering to identify, formulate, and solve chemical engineering problems as well as to design and conduct experiments safely and analyze and interpret data. They are prepared to pursue advanced studies in chemical engineering. Program graduates gain a sense of professional and ethical responsibility with the ability to apply environmental, safety, economic, and ethical criteria in the design of engineering processes. They learn to function in individual and group working environments, and learn skills in written and oral communication and the effective use of computers for engineering practice, including information search in the library and on the Internet. They also understand the need for lifelong learning and the significance of societal and global issues relevant to chemical engineering.

A minimum of 130 credits is required for graduation with the degree of bachelor of science in chemical engineering. There are nine electives in the chemical engineering curriculum. Five of these are for the general education requirements. The remaining four electives should consist of three chemical engineering electives and one additional technical elective.

Students are required to obtain a minimum 2.0 grade-point average in CHE 501-502 and in overall standing at the end of the sophomore year in order to continue in the major.

Freshman Year	**Fall**	**Spring**
ENGL 401, Freshman English	4	-
Math 425-426, Calculus I and II	4	4
PHYS 407, General Physics I	-	4
CHEM 405, General Chemistry	4	-
CHE 410, Energy and Environment	4	-
Electives (2)	-	8
Total	**16**	**16**

Sophomore Year	Fall	Spring
CHEM 683-684, Physical Chemistry I and II	3	3
CHEM 685-686, Physical Chemistry Laboratory	2	2
MATH 527, Differential Equations with Linear Algebra	4	-
CS 410, Introduction to Scientific Programming	-	4
PHYS 408, General Physics II	4	-
CHE 501-502, Introduction to Chemical Engineering I and II	3	3
Elective	-	4
Total	**16**	**16**

Junior Year	Fall	Spring
CHEM 651-652, Organic Chemistry	3	3
CHEM 653, Organic Chemistry Laboratory	2	-
CHE 601, Fluid Mechanics and Unit Operations	3	-
CHE 602, Heat Transfer and Unit Operations	-	3
CHE 603, Applied Mathematics for Chemical Engineers	4	-
CHE 604, Chemical Engineering Thermodynamics	-	4
CHE 612, Chemical Engineering Lab. I	-	3
Electives (2)	4	4
Total	**16**	**17**

Senior Year	Fall	Spring
CHE 703, Mass Transfer and Stagewise Operations	3	-
CHE 707, Chemical Engineering Kinetics	3	-
CHE 708, Chemical Engineering Design	-	4
CHE 713, Chemical Engineering Laboratory II	3	-
CHE 752, Process Dynamics and Control	-	4
Electives (4)	8	8
Total	**17**	**16**

Bioengineering Option

Under this option, the required courses deal with the application of basic biological sciences and chemical engineering principles to the design and operation of large-scale bioprocesses for the production of high-value medicinal products, food and beverage, pharmaceutical, biomedical, genetic engineering products, and health care products. The elective courses permit the student to study topics of special interest in more depth or gain a broader perspective in bioengineering or some closely related subjects such as biochemistry or biotechnology experience in manufacturing or research. Three courses are required, and a minimum of two additional courses of at least three credits each should be selected from the electives list. Students interested in the bioengineering option should declare their intention to the department faculty during the sophomore year. They may consult with P.T. Vasudevan, (603) 862-2298.

Required Courses	Credits
CHE 761, Biochemical Engineering	4
CHE 762, Biomedical Engineering	4
BCHM 658, General Biochemistry	3
BCHM 659, General Biochemistry Laboratory	2
Total	**13**

Elective Courses	Credits
CHE 695, Chemical Engineering Project	3-4
CHE 696, Independent Study	3-4
BIOL 404, Biotechnology and Society	4
BCHM 751, Principles in Biochemistry	4
BCHM 752, Principles in Biochemistry	4
BCHM 750, Physical Biochemistry	3
BTEC 210, Biotech Experience: Research* (NHBET, Pease)	4
BTEC 220, BioTech Experience: Manufacturing*	4
MATH 740, Design of Experiments I	4
Total	**6-8**

*BTEC 210 and BTEC 220 are cross-listed as MICR 655 and MICR 651

Energy Option

This option covers the major areas of current interest in the energy field. The required courses provide students with a general background knowledge of fossil fuels, nuclear power, solar energy, and other alternative energy resources. The elective courses will permit the student to study topics of special interest in more depth or gain a broader perspective on energy and some closely related subjects. Three courses are required, and a minimum of two additional courses of at least three credits each should be selected from the electives list. Students interested in the energy option should declare their intention to the department faculty during the sophomore year. They may consult with P.T. Vasudevan, (603) 862-2298.

Required Courses	Credits
CHE 705, Natural and Synthetic Fossil Fuels	4
CHE 712, Introduction to Nuclear Engineering	4
CHE 761, Biochemical Engineering	4
Total	**12**

Elective Courses	Credits
CHE 695, Chemical Engineering Project	3-4
CHE 696, Independent Study	3-4
ENE 772, Physicochemical Processes for Water/Air Quality	4
MATH 740, Design of Experiments I	4
Total	**6-8**

Environmental Engineering Option

The chemical engineering program, with its substantial requirements in chemistry, fluid dynamics, heat transfer, mass transfer, unit operations, and reaction kinetics, provides students with a unique preparation to deal with many aspects of environmental pollution problems. The option gives students a special focus on the application of chemical engineering principles and processes to the solution of problems relating to air pollution, water pollution, and the disposal of solid and hazardous waste. Three required courses must be selected, plus two electives from the electives list. Each course must carry a minimum of three credits. Students interested in the environmental engineering option should declare their intention to the department faculty during the sophomore year. They may consult with P.T. Vasudevan, (603) 862-2298.

Required Courses	Credits
ENE 709, Fundamentals of Air Pollution and Its Control	4
ENE 772, Physicochemical Processes for Water/Air	4
ENE 742, Solid and Hazardous Waste Engineering	3
Total	**11**

Elective Courses	Credits
CHE 695, Chemical Engineering Project	3-4
CHE 696, Independent Study	3-4
CHE 744, Corrosion	4
ENE 746, Bioenvironmental Engineering Design	3
ENE 749, Water Chemistry	4
MATH 740, Design of Experiments I	4
Total	**6-8**

Chemistry (CHEM)

www.unh.edu/chemistry/

(For course descriptions, see page 165.)

Professor: Christopher F. Bauer, Arthur Greenberg, Richard P. Johnson, Howard R. Mayne, Glen P. Miller, W. Rudolf Seitz, Sterling A. Tomellini, Gary R. Weisman, Edward H. Wong, Charles K. Zercher

Associate Professor: Roy Paul Planalp

Assistant Professor: Margaret E. Greenslade, Samuel Pazicni

"Chemistry is everywhere. From agriculture to health care, chemistry extends life and improves its quality. From disposable diapers to space suits, chemistry provides new materials for clothing, shelter, and recreation. From computer chips to fiber optics, chemistry is the foundation of today's high technology." (American Chemical Society)

A study in chemistry is the pathway to multiple options. These options include careers in education, law, forensics, medicine, biotechnology, environmental protection, technical sales, pharmaceutical research, semiconductors, and industrial chemical production. The potential is limitless. Students interested in pursuing chemistry as an undergraduate degree have three options available to them, which are based on their career plans. These are the bachelor of science degree; a bachelor of arts degree; and a bachelor of arts, chemistry and physics teaching degree. Since the required chemistry courses in each degree program are the same the first year, it is easy to change from one program to another.

In general, a first-year student should register for the following courses, and this applies to all three programs: First Semester: Freshman Seminar, Chemistry 400; General Chemistry with lab, Chemistry 403; Calculus I, Mathematics 425; Second Semester: General Chemistry with lab, Chemistry 404; Calculus II, Mathematics 426; Freshman English, English 401W.

Requirements

1. Satisfy general education requirements.
2. For specific course requirements, see the accompanying chart.

Bachelor of Arts in Chemistry

This curriculum offers students the opportunity to combine the chemistry major with other interests; for example, preprofessional programs, education, and business.

Requirements

1. Satisfy general education requirements.
2. Satisfy the bachelor of arts degree requirements.
3. For specific course requirements, see the accompanying chart.

Baccalaureate Degree Required Chemistry Courses	B.S.	B.A.
400, Freshman Seminar	x	x
403, 404, General Chemistry	x	x
517, 518, Quantitative Analysis	x	x
547 & 549, Organic Chemistry I	x	x
548 & 550, Organic Chemistry II	x	x
574, Introduction to Inorganic Chemistry	x	x
683 & 685, Physical Chemistry I	x	x
684 & 686, Physical Chemistry II	x	x
762 & 763, Instrumental Methods of Chemical Analysis	x	x
698, Seminar	x	x
699, Thesis	x	
755 & 756, Advanced Organic Chemistry	x	
774 & 775, Advanced Inorganic Chemistry	x	
776, Physical Chemistry III	x	
708, Spectroscopic Investigations of Organic Molecules		

Other Requirements

All majors: MATH 425 and 426, Calculus I and II.

B.A.s are required to take 698, Seminar; it also meets writing intensive requirements.

B.S. degree: PHYS 407-408, General Physics I and II; BCHM 658 or 751, Biochemistry; one chemistry-related course.$

B.A. degree, chemistry major: PHYS 407, General Physics I, or PHYS 401-402, Introduction to Physics I and II; two other CHEM courses, except 698, or two approved chemistry-related courses.

$ Suggested courses: MATH 527, 528; PHYS 505; EE 620; BCHM 658, 751.

Bachelor of Arts, Chemistry and Physics Teaching

This major is designed for students who wish to teach chemistry and physics in secondary schools. The number of positions available for teaching chemistry or physics alone is limited, but many opportunities exist to teach both subjects on the secondary-school level. Chemistry and physics teaching majors will have good preparation for teaching these subjects and will have the necessary mathematics and education background.

Requirements

1. Satisfy general education requirements.

2. Satisfy the bachelor of arts degree requirements.

3. Chemistry requirements: 400, Freshmen Seminar; 403-404, General Chemistry; 517, 518, Quantitative Analysis; 545, 546 or 547-548 and 549-550, Organic Chemistry; 683-684 and 685-686, Physical Chemistry I and II.

4. Physics requirements: 407, General Physics I; 408, General Physics II; 505, General Physics III; 605, Experimental Physics I. PHYS 406, Introduction to Modern Astronomy, is strongly recommended.

5. Math requirements: 425, Calculus I, and 426, Calculus II.

6. All education courses in the teacher preparation program.

Bachelor of Science in Chemistry

This curriculum prepares students for careers requiring a thorough knowledge of chemistry and provides a strong foundation for careers in industry, professional schools (e.g., medical schools), and for graduate study in chemistry or in interdisciplinary areas. The curriculum requires a greater depth in chemistry and physics than do the other degree programs.

Requirements

1. Satisfy general education requirements.

2. For specific course requirements, see Baccalaureate Degree Required Chemistry Courses.

General Science Certification

Students majoring in animal sciences, biochemistry, biology, environmental conservation studies, environmental sciences, forestry, microbiology, plant biology, wildlife management, or zoology may seek certification to teach science at the middle, junior, or high school level.

For further information, contact the coordinator of teacher education in the Department of Education and see College of Life Sciences and Agriculture/Degrees, page 89.

Civil Engineering (CIE)

www.unh.edu/civil-engineering/

(For course descriptions, see page 167.)

Chairperson: Jean Benoit

Professor: Jean Benoit, M. Robin Collins, Pedro A. de Alba, David L. Gress, Nancy E. Kinner, James P. Malley Jr.

Research Professor: T. Taylor Eighmy

Associate Professor: Thomas P. Ballestero, Raymond A. Cook, Jo S. Daniel, Kevin H. Gardner, Charles H. Goodspeed, Robert M. Henry, Jennifer M. Jacobs

Assistant Professor: Erin S. Bell, Ricardo A. Medina

Research Assistant Professor: Jeffrey S. Melton, Robert M. Roseen

Civil engineering involves the planning, design, and construction of public works: buildings, bridges, roads, dams, water transmission systems, water treatment systems, tunnels, and more. These facilities must provide efficient service, be cost-effective, and be compatible with the environment. Moreover, civil engineers work under a code of ethics in which their primary, overriding responsibility is to uphold the public's trust by working to plan, design, build, and restore safe and environmentally responsible public works.

Civil engineers work as private consultants and for government agencies in a wide variety of indoor and outdoor settings around the world. There is a strong and constant market for civil engineers due to the demands placed on the profession to construct, maintain, and repair the infrastructure.

As civil engineering is such a broad field, it is traditionally divided into several sub-disciplines. At the University of New Hampshire, five are offered: civil engineering materials, environmental engineering, geotechnical engineering, structural engineering, and water resources engineering. Civil engineering majors may choose the sub-discipline in which to focus their studies during their senior year. Additionally, the College of Engineering and Physical Sciences, through the Departments of Civil Engineering and Chemical Engineering, offers a B.S. in environmental engineering (ENE), which is a major for students who choose to specifically focus their attention solely in that area. (Students who are interested in environmental engineering but who also want a broader or more traditional civil engineering focus should pursue the civil engineering major and elect environmental engineering courses in their senior year.) Students may readily transfer between the civil engineering (CIE) and ENE programs within the first two semesters. Both the B.S. in civil engineering and the B.S. in environmental

engineering provide a firm base in mathematics, science, and engineering, and all majors are expected to develop excellent communication and computer skills. Graduates are prepared to enter the profession and to pursue advanced study. Because of the broad technical background attained, some graduates also successfully pursue further education in business, architecture, education, and law.

Mission

The mission of the Department of Civil Engineering is to pursue and disseminate knowledge through teaching, research, and public service. As part of its teaching mission, the department provides rigorous, yet flexible, undergraduate and graduate education for both traditional and nontraditional students through classical and creative instruction in the classroom, laboratory, and field. While preparing students for the profession, the department offers an education in civil engineering that includes working in multidisciplinary teams that critically analyze and formulate solutions to civil engineering problems and apply engineering principles that provide social, economic, and environmental benefits to the public. The department encourages in its students a lifelong desire to keep abreast of new developments in the field and teaches them the skills necessary to continue learning. As part of its research mission, the department maintains a rigorous multidisciplinary program of scholarship advancing the state of the art in civil engineering. As part of its mission in public service, the department enhances the quality of life for people, especially in New England and specifically New Hampshire, by providing expert services, advancing and transferring knowledge and technology, and serving as a resource for information.

Educational Objectives

In accordance with its University, college, and department missions, the faculty of the Department of Civil Engineering has established clear objectives for students to help them become successful professionals after graduation. To assist graduates to become practicing civil engineers, the program helps students achieve a basic competence in math, science, and engineering principles; learn how to apply this knowledge to solve engineering problems; achieve a working knowledge in the basic civil engineering areas of structural engineering, geotechnical engineering, civil engineering materials, water resources, environmental engineering, and project engineering; and extend their knowledge in one or more of these areas. As part of this process, students learn how to critically analyze and design equipment, structures, systems, or processes to meet desired needs; and to use current, and be able to independently learn new, engineering software. Engineers also need to be effective communicators. Engineering students learn how to communicate and defend ideas in technical reports and correspondence, how to speak before a group and convey information to technical and non-technical audiences, and how to create and effectively use graphics in support of a presentation or report. Students also learn how to work effectively as good team players who are also capable of being members of multidisciplinary teams.

As part of finding engineering solutions, students learn to locate, compile, and use existing information; design and perform experiments to gather new information; critically analyze information; and draw conclusions. Due to the nature of civil engineering efforts, which involve the public, public safety, and significant financing, it is imperative that graduates become good engineering citizens. Students develop an awareness of the interaction between engineering practice and social, economic, and environmental issues; the importance of the ASCE Code of Ethics; an awareness of contemporary issues in their interaction with civil engineering practice; and the importance of broadening their education by being familiar with topics outside of the math, science, and engineering areas. Civil engineers also are professionals who often are licensed practitioners. Students are prepared to take the Fundamentals of Engineering examination (which is required for professional licensure), understand the need for lifelong learning, and actively participate in organizations such as ASCE, SWE, SWB, Tau Beta Pi, and the Order of the Engineer.

Bachelor of Science in Civil Engineering

Matriculating students should have strong aptitudes in mathematics and science along with imagination, spatial and graphic abilities, communication skills, and creativity. Students then follow a four-year program that conforms to the guidelines of, and is accredited by, the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

The first two years of the program provide the necessary technical knowledge in mathematics, chemistry, and physics, while introducing and developing civil engineering problem-solving techniques. The junior year provides courses in each of the civil engineering sub-disciplines, providing students with skills in each and allowing students to determine which they wish to pursue further. The senior year is flexible, allowing students to choose where to focus attention by selecting from more than thirty elective courses in civil and environmental engineering.

The required curriculum includes eight writing-intensive courses, thereby not only satisfying but exceeding the University's writing requirement. (See University Academic Requirements.)

Electives

Approximately one-third of the major's total credits and more than half of the senior-level courses are elected by the student. Of these, there are general education electives required by the University and other electives required by the department in order to satisfy departmental objectives and accreditation requirements.

1. The general education program is described in University Academic Requirements. Courses required by the civil engineering major fulfill the Group 1 through Group 3 general education requirements. Therefore, students select electives to satisfy the Group 4 through Group 8 courses—one elective per group.

2. The civil engineering major also requires students to select one math and basic sciences elective. A list of courses that fulfill this elective is available from the department.

3. Civil engineering majors wishing to participate in exchange programs must achieve a cumulative grade point average of 3.0 or better in all MATH, PHYS, CHEM, CIE, and ENE courses taken to date at the end of each of the second and third semesters prior to their exchange semester.

4. In the senior year, students take four courses specific to civil engineering sub-disciplines, and a senior science elective. Students can use these electives to focus on a particular civil engineering area or can acquire a broader perspective by taking courses in a variety of areas. At least one of these four elective courses must qualify also as a civil engineering design elective, and no more than three courses may be taken in one sub-discipline. Lists of courses that fulfill these electives are available from the department.

Additional program policies and requirements

1. To transfer into the civil engineering major, a student must have the following:

   a. an overall grade-point average of 2.33 or greater;

   b. an overall grade-point average of 2.33 or greater for all CIE and ENE courses taken to-date;

   c. a grade-point average of 2.33 in courses taken to-date of MATH 425; PHYS 407; CHEM 405 or CHEM 403; CIE 525; and CIE 526;

   d. a minimum grade of C+ in courses taken to-date of CIE 525 and CIE 526.

2. Students who are transferring into the civil engineering major may only transfer in the following:

   a. a maximum of 20 credits for CIE and ENE 600- and 700-level coursework,

   b. CIE and ENE 600- and 700-level courses in which the student has received a grade of C- or better.

3. To continue as a civil engineering major, a student must adhere to the following restrictions:

a. a maximum of two CIE or ENE courses may be repeated (though each of these may be repeated more than once),

b. a semester grade-point average lower than 2.0 may be earned for a maximum of two consecutive semesters,

c. a cumulative grade-point average of less than 2.0 for CIE and ENE courses may be earned for a maximum of any two semesters.

4. CIE and ENE 600- and 700-level courses are intended for CIE and ENE majors only. All others may enroll in these courses only with the permission of the instructor, but others may take no more than 20 credits of these courses.

5. To enter the required 600-level courses in the junior year, students must achieve the following:

a. the completion of CIE 525, CIE 526, MATH 425, PHYS 407, and CHEM 405 or CHEM 403,

b. an overall grade-point average of 2.0 or greater for these courses,

c. a grade of C or better in each of CIE 525 and CIE 526.

6. To graduate with a bachelor of science in civil engineering, a student must achieve the following:

a. 129 or more credits,

b. credit for the civil engineering program's major and elective courses,

c. satisfaction of the University's general education requirements,

d. satisfaction of the University's writing intensive course requirements,

e. a cumulative grade-point average of 2.0 or better for all courses,

f. a cumulative grade-point average of 2.0 or better for all CIE and ENE courses.

First Year	Fall	Spring
CIE 402, Intro. to Civil Engineering	3	-
ENGL 401, First-Year Writing	4	-
TECH 564, Fundamentals of CAD	3	-
Elective (2) general education requirement*	4	4
CIE 505, Surveying and Mapping	-	4
MATH 425, Calculus I	-	4
PHYS 407, General Physics I	-	4
Total	**14**	**16**

Sophomore Year	Fall	Spring
CIE 525, Statics	3	-
ENE 520, Environmental Pollution and Protection	4	-
ENGL 502, Technical Writing	4	-
MATH 426, Calculus II	4	-
PHYS 408, General Physics II	4	-
CHEM 405, General Chemistry	-	4
CIE 526, Strength of Materials	-	3
CIE 533, Project Engineering	-	3
MATH 527, Differential Equations with Linear Algebra	-	4
Elective (1) general education requirement*	-	4
Total	**19**	**18**

Junior Year	Fall	Spring
CIE 622, Engineering Materials	4	-
CIE 642, Fluid Mechanics	4	-
MATH 644, Statistics for Engineers and Scientists	4	-
Elective (1) math and basic sciences**	4	-
CIE 665, Soil Mechanics	-	4
CIE 681, Classical Structural Analysis	-	3
ENE 645, Fundamental Aspects of Environmental Engineering	-	4
Elective (1) general education requirement*	-	4
Total	**16**	**15**

Senior Year	Fall	Spring
CIE 760, Foundation Design I	4	-
CIE 774, Reinforced Concrete Design	4	-
CIE 784, Intro. to Project Planning and Design	1	-
Elective (1) senior science**	3	-
CIE or ENE 788, Project Planning and Design	-	3
Elective (4) civil engineering**	3	9
Elective (1) general education requirement*	-	4
Total	**15**	**16**

Computer Science (CS)

www.cs.unh.edu

(For course descriptions, see page 173.)

Chairperson: Philip J. Hatcher

Professor: R. Daniel Bergeron, Philip J. Hatcher, Ted M. Sparr, Colin Ware

Associate Professor: Radim Bartos, Michel Charpentier, Robert D. Russell, Elizabeth Varki, James L. Weiner

Affiliate Associate Professor: Jason H. Moore, Sylvia Weber Russell

Assistant Professor: Wheeler Ruml

Affiliate Assistant Professor: Anthony J. Lapadula, Matthew Plumlee

Instructor: Michael Gildersleeve, Brian L. Johnson, Israel J. Yost

Lecturer: Mark L. Bochert, Ellen M. Hepp, Karl Shump

Computer Science

Undergraduate students may choose from one of three degree options: The B.S. in computer science, which is designed for students interested in the design and implementation of software systems; the B.S. in computer science: bioinformatics option, which is designed for students who wish to apply computer science expertise in the life sciences; and the B.S. in information technology, which focuses on the application of existing computing technologies to the information needs of organizations and individual computer users.

*See University Academic Requirements for general education requirements.

** Approved list available in the CIE office.

Bachelor of Science in Computer Science

Computer scientists are concerned with problem-solving in general, with particular emphasis on the design of computer-efficient solutions. This involves a detailed understanding of the nature of algorithms, the software implementation necessary to utilize algorithms on computers, and how algorithms can be combined in a structured manner to form highly complex systems.

The broad objectives for B.S. in Computer Science graduates are:

1. To be competent in formulating and solving computer science problems, including the development of complex software systems;

2. To understand computer science fundamentals along with supporting mathematics and science so they will be prepared for a wide range of jobs and the pursuit of advanced degrees;

3. To be able to function in the workplace with the necessary technical skills and with appropriate oral and written communication skills; and

4. To have a broad education that promotes professional advancement, lifelong personal development, and social responsibility.

The B.S. in computer science program is accredited by the Computing Accreditation Commission of ABET, 111 Market Place, suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

The program is designed to prepare students for employment and/or graduate study. Most courses require heavy computer use, and the laboratories stress hands-on experience with building software systems.

Computer science majors must maintain an overall grade-point average of 2.0 or better in all required computer science, mathematics, and computer engineering courses in order to graduate. If at the end of any semester, including the first, a student's cumulative grade-point average in these courses falls below 2.0, the student may not be allowed to continue as a CS major. In order to be able to take a CS or MATH course with prerequisites, the prerequisite course(s) must be passed with a grade of a C- or better.

If a student wishing to transfer into the computer science major has any coursework that is applicable to the major, the grades in those courses must satisfy the minimum grade requirements for the B.S. degree in computer science. The student must have an overall grade-point average of 2.0 or better in all courses taken at the University.

The curriculum includes coursework in mathematics, science, and philosophy. The following is a sample schedule depicting the necessary requirements and the layout of the curriculum. Students must consult with their advisers in order to come up with the proper schedule for themselves.

Freshman Year	Fall	Spring
CS 400, Introduction to Computing	1	-
CS 415, Introduction to Computer Science I	4	-
MATH 425, Calculus I (Gen Ed 2)	4	-
Gen Ed 3 (Science/Technology)*	4	-
Gen Ed	4	-
CS 416, Introduction to Computer Science II	-	4
MATH 426, Calculus II	-	4
ENGL 401, First-Year Writing (Gen Ed 1)	-	4
Gen Ed 3 (Science/Technology)*	-	4
Total	**17**	**16**

* These two additional technology or science courses are required, in addition to PHYS 407 and 408. One will satisfy a general education requirement. Students can choose these two courses from the following list:

Biology:
BIOL 411, Principles of Biology I
BIOL 412, Principles of Biology II
BIOL 413, Principles of Biology I (UNH Manchester Course)
BIOL 414, Principles of Biology II (UNH Manchester Course)
HMP 501, Epidemiology and Community Medicine
MICR 501, Public Health Microbiology
PBIO 412, Introductory Botany
PBIO 421, Concepts of Plant Growth
ZOOL 412, Principles of Zoology

Physical Science:
CHEM 401-402, Introduction to Chemistry
CHEM 403-404, General Chemistry
CHEM 405, General Chemistry
ESCI 405, Global Environmental Change
ESCI 409, Environmental Geology
ESCI 501, Introduction to Oceanography
NR 504, Freshwater Resources

Technology:
PHIL 447, Computer Power and Human Reason

Sophomore Year	Fall	Spring
CS 515, Data Structures	4	-
MATH 531, Mathematical Proof	4	-
PHYS 407, General Physics I (Gen Ed 3P)	4	-
Gen Ed	4	-
CS 516, Intro to Software Design and Development	-	4
MATH 532, Discrete Mathematics	-	4
PHYS 408, General Physics II (Gen Ed 3P)	-	4
Gen Ed	-	4
Total	**16**	**16**

Junior Year	Fall	Spring
CS 520, Assembly Language Programming and Machine Organization	4	-
CS 671, Programming Language Concepts and Features	4	-
Statistics Course*	4	-
PHIL 424, Science, Technology and Society (Gen Ed 8)	4	-
CS 620, Operating System Fundamentals	-	4
Computer Science Theory Course**	-	4
ECE 543, Introduction to Digital Systems	-	4
Gen Ed	-	4
CS 595, Computer Science Seminar	-	2
Total	**16**	**18**

* Statistics requirement can be fulfilled by MATH 539, Introduction to Statistical Analysis, or MATH 644, Statistics for Engineers and Scientists.

**CS Theory requirement can be fulfilled by CS 645, Introduction to Formal Specification and Verification, or CS 659, Introduction to the Theory of Computation.

Senior Year	Fall	Spring
CS 719, Object-Oriented Methodology	4	-
CS Writing-Intensive Course	4	-
ECE 562, Computer Organization	4	-
Liberal Arts Elective*	4	-
CS 700-Level Elective	-	4
CS 700-Level Elective	-	4
Liberal Arts Elective*	-	4
Free Elective	-	1
Total	**16**	**13**

*Liberal Arts electives can be any course within the College of Liberal Arts that does not have a math or science component.

Bachelor of Science in Computer Science: Bioinformatics Option

The bioinformatics field is an increasingly important sub-discipline in computer science. The demand for computer science graduates who can apply their knowledge in the life sciences is significant, and is expected to continue to grow. Students who choose this path are still computer science majors but have a concentration in the life sciences. The option has the same core as the B.S. program but requires appropriate coursework in chemistry, biology, biochemistry, and statistics.

Computer science: bioinformatics majors must maintain an overall grade-point average of 2.0 or better in all required computer science, mathematics, computer engineering, biology, and biochemistry courses in order to graduate. If at the end of any semester, including the first, a student's cumulative grade-point average in these courses falls below 2.0, the student may not be allowed to continue as a computer science: bioinformatics major. In order to be able to take a CS or MATH course with prerequisites, the prerequisite course(s) must be passed with a grade of a C- or better.

If a student wishing to transfer into the computer science: bioinformatics major has any coursework that is applicable to the major, the grades in those courses must satisfy the minimum grade requirements for the B.S. degree in computer science. The student must have an overall grade-point average of 2.0 or better in all courses taken at the University.

The B.S. in computer science: bioinformatics program is accredited by the Computing Accreditation Commission of ABET, 111 Market Place, suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

The broad objectives for B.S. in Computer Science: Bioinformatics graduates are:

1. To be competent in formulating and solving computer science problems, including the development of non-trivial software systems;

2. To understand computer science fundamentals along with supporting mathematics and science so they will be prepared for a wide range of jobs in the biomedical industry and the pursuit of advanced degrees in both computer science and bioinformatics;

3. To be able to function in the workplace with the necessary technical skills and with appropriate oral and written communication skills; and

4. To have a broad education that promotes professional advancement, lifelong personal development, and social responsibility.

The following is a sample schedule depicting the necessary requirements and the layout of the curriculum. Students must consult with their advisers in order to come up with the proper schedule for themselves.

Freshman Year	Fall	Spring
CS 400, Introduction to Computing	1	-
CS 415, Introduction to Computer Science I	4	-
MATH 425, Calculus I (Gen Ed 2)	4	-
BIOL 411, Principles of Biology I (Gen Ed 3B)	4	-
Gen Ed	4	-
CS 416, Introduction to Computer Science II	-	4
MATH 426, Calculus II	-	4
BIOL 412, Principles of Biology II (Gen Ed 3B)	-	4
ENGL 401, First-year Writing (Gen Ed 1)	-	4
Total	**17**	**16**

Sophomore Year	Fall	Spring
CS 515, Data Structures	4	-
MATH 531, Mathematical Proof	4	-
CHEM 403, General Chemistry I (Gen Ed 3P)	4	-
Gen Ed	4	-
CS 516, Introduction to Software Design and Development	-	4
MATH 532, Discrete Mathematics	-	4
CHEM 404, General Chemistry II (Gen Ed 3P)	-	4
Gen Ed	-	4
Total	**16**	**16**

Junior Year	Fall	Spring
CS 520, Assembly Language Programming and Machine Organization	4	-
Statistics Course*	4	-
CS 671, Programming Language Concepts and Features	4	-
PHIL 424, Science, Technology and Society (Gen Ed 8)	4	-
CS 595, Computer Science Seminar	2	-
CS 620, Operating System Fundamentals	-	4
Computer Science Theory Course**	-	4
BIOL 604, Principles of Genetics	-	4
Gen Ed	-	4
Total	**18**	**16**

*Statistics requirement can be fulfilled by MATH 539, Introduction to Statistical Analysis, or MATH 644, Statistics for Engineers and Scientists.

**CS Theory requirement can be fulfilled by CS 645, Introduction to Formal Specification and Verification, or CS 659, Introduction to the Theory of Computation.

Senior Year	Fall	Spring
CS 719, Object-Oriented Methodology	4	-
BCHEM 711, Genomics and Bioinformatics	4	-
700-level Statistics Course*	4	-
Liberal Arts Elective	4	-
CS Writing Intensive Course**	-	4
CS 775, Database Systems	-	4
ECE 543, Introduction to Digital Systems	-	4
Liberal Arts Elective	-	4
Total	16	16

*This requirement can be fulfilled by the following courses: MATH 739, Applied Regression Analysis; MATH 742, Multivariate Statistical Methods; or MATH 755, Probability and Stochastic Processes with Applications.

** This course must include a project that addresses bioinformatics issues.

The Minor in Computer Science

The minor in computer science is designed for students in other majors who want to learn the fundamentals of designing and implementing computer software.

Requirements:

CS 415, Introduction to Computer Science I
CS 416, Introduction to Computer Science II
CS 515, Data Structures

Two additional courses chosen from:

CS 516, Introduction to Software Design and Development
CS 520, Assembly Language Programming and Machine Organization
CS 620, Operating System Fundamentals
*CS 645, Introduction to Formal Specification and Verification
*CS 659, Introduction to the Theory of Computation
CS 671, Programming Language Concepts and Features
An approved CS 700-level course

* CS 645 and 659 have mathematics prerequisites: MATH 425, MATH 426, MATH 531, and MATH 532.

Note: All courses for the minor must be completed with a C- or higher.

The Bachelor of Science in Information Technology

Information technology is concerned primarily with the application of existing computing technologies to the information needs of organizations and individual computer users. Potential careers include network administrator, database administrator, system administrator, and Web site administrator.

IT programs aim to provide graduates with the skills and knowledge to take on appropriate professional positions in information technology upon graduation and grow into leadership positions in the field. Specifically, within five years of graduation a student must be able to:

1. Explain and apply appropriate information technologies and employ appropriate methodologies to help an individual or organization achieve its goals and objectives;

2. Manage the information technology resources of an organization;

3. Anticipate the changing direction of information technology and evaluate and communicate the likely utility of new technologies to an organization;

4. Demonstrate professional advancement, lifelong personal development, and social responsibility.

The B.S. in information technology degree program was approved by the College of Engineering and Physical Sciences in May 2008 and the USNH Board of Trustees in fall 2008. The University will welcome its first IT class in fall 2009. Note: the B.S. in information technology degree program has not yet been accredited by the Accreditation Board for Engineering and Technology.

Information technology majors must maintain an overall grade-point average of 2.0 or better in all required information technology and computer science required courses in order to graduate. If at the end of any semester, including the first, a student's cumulative grade-point average in these courses falls below 2.0, the student may not be allowed to continue as an IT major. All required IT courses offered by the CS department at the 400-600 level must be passed with a C- or better.

If a student wishing to transfer into the information technology major has any coursework that is applicable to the major, the grades in those courses must satisfy the minimum grade requirements for the B.S. degree in Information Technology. The student must have an overall grade-point average of 2.0 or better in all courses taken at the University.

The IT major requires students to take the equivalent of 10 courses within the CS department that constitute the core coverage of the breadth of IT topics. In addition, students much choose a depth track, consisting of three courses that focus on a more specialized area within the IT field. The CS department currently offers a Web track and an Admin track. Students who choose the Web Track must take IT 604, Intermediate Web Development; CS 771, Web Programming Paradigms; and IT 704, Advanced Web Topics. Students who opt for the Admin Track must take IT 609, Network/System Administration; IT 725, Network Technology; and IT 775, Database Technology.

The IT curriculum includes a number of courses outside of the CS department. Two courses in mathematics are required: Calculus I and a statistics course. A two-semester lab science sequence is also required, as are a philosophy course (PHIL 424) and a technical writing course (ENGL 502).

In addition, by the end of their sophomore year, each student must choose a second discipline – a particular domain outside of IT to which the student's IT skills can be applied. Second disciplines (typically five courses) have been defined by the CS department in such areas as business administration, health management and policy, and justice studies. If a student is interested in an area that is not currently defined, the option of a student-designed second discipline is also available.

The following is a sample schedule depicting the necessary requirements and the layout of the curriculum. Students must consult with their advisers in order to come up with the proper schedule for themselves.

Freshman Year	Fall	Spring
CS 400, Introduction to Computing	1	-
MATH 425, Calculus I, Gen Ed	-	4
CS 403, Weaving the Web (Gen Ed 3)	4	-
CS 415, Introduction to Computer Science I	4	-
Gen Ed	4	-
IT 506, Intermediate Applications Programming with Visual Basic *or* CS 416, Introduction to Computer Science II	-	4
IT 502, Intermediate Web design	-	4
ENGL 401, First-year Writing (Gen Ed 1)	-	4
Total	**17**	**16**

Sophomore Year	Fall	Spring
MATH 439, Statistical Discovery for Everyone	4	-
IT 520, Computer Architecture	4	-
Gen Ed	4	-
Lab Science I & II (Gen Ed 3B or 3P)	4	4
IT 505, Database Programming	-	4
ENGL 502, Technical Writing	-	4
Second Discipline I	-	4
Total	**16**	**16**

Junior Year	Fall	Spring
Depth Track I	4	-
PHIL 424, Science, Technology and Society (Gen Ed 8)	4	-
Second Discipline II	4	-
Gen Ed	4	-
CS 600, Internship	-	1
CS 595, Computer Science Seminar	-	2
Depth Track II	-	4
IT 666, Computer Security	-	4
Second Discipline III	-	4
Total	**16**	**15**

Senior Year	Fall	Spring
Depth Track III	4	-
Second Discipline IV	4	-
Free Elective	4	-
IT 705, Project Management	4	-
IT 710, Senior Project	-	4
Second Discipline V	-	4
Free Elective	-	4
Free Elective	-	4
Total	**16**	**16**

Minor in Information Technology

The information technology (IT) minor is a way for students in non-technical majors to bridge the gap between a primarily non-technical education and a technical world. Graduates from a variety of fields are discovering that there is a great need to have computer competency in addition to the knowledge they gain in their major; and, the IT minor, which is tailored to grow students' understanding of computer and information technology applications, helps prepares students for the future.

Students who minor in IT must complete a minimum of 20 credits of IT courses. All students must take IT 520, Computer Architecture, as well as an introductory programming course. The other three courses may be chosen from the list below.

Credit toward the minor will be given only for courses passed with C- or better, and a 2.0 grade-point average must be maintained in courses for the minor. Courses taken on the pass/fail basis may not be used for the minor. Students should declare their intent to earn a minor as early as possible and no later than the end of the junior year. During the final term, an application should be made to the dean of the student's major college to have the minor shown on the academic record. Students must consult with their major adviser and also the minor supervisor.

Requirements:

1. IT 520, Computer Architecture

2. A programming course chosen from the following list:
   - CS 405, Introduction to Applications Programming with Visual Basic
   - CS 410, Introduction to Scientific Programming
   - CS 503, Introduction to Web Programming

3. Three courses from the following list (at least two of which must be at the 500/600-level):
   - CS 401, Computer Applications
   - CS 403, Weaving the Web: Creating Content for the World Wide Web
   - IT 502, Intermediate Web Design
   - IT 505, Database Programming
   - IT 506, Intermediate Applications Programming with Visual Basic
   - IT 604, Intermediate Web Development
   - IT 609, Network/System Administration

Earth Sciences (ESCI)

www.unh.edu/esci/

(For course descriptions, see page 175.)

Chairperson: William C. Clyde

Professor: Larry A. Mayer

Research Professor: Janet W. Campbell, Robert W. Talbot

Affiliate Professor: Andrew Armstrong, P. Thompson Davis, Jim Gardner, Peter J. Thompson, Charles J. Vorosmarty, David R. Wunsch

Associate Professor: William C. Clyde, J. Matthew Davis, Jo Laird, Joseph M. Licciardi, James M. Pringle

Research Associate Professor: Jack E. Dibb, Stephen E. Frolking, Thomas C. Lippmann, Cameron P. Wake, Larry G. Ward

Affiliate Associate Professor: Mark A. Fahnestock, Robert J. Griffin, Huiting Mao, Douglas C. Vandemark

Assistant Professor: Margaret S. Boettcher, Julia G. Bryce, Joel E. Johnson, Linda Kalnejais

Research Assistant Professor: Ruth K. Varner

Affiliate Assistant Professor: Jeffrey B. Johnson, John R. Morrison, Wilfred M.Wollheim

The courses offered in the Department of Earth Sciences cover the broad spectrum of geosciences, with emphases on geology, hydrology, geochemistry, and oceanography. The curriculum encompasses a group of related studies concerned with an understanding of the Earth and its environment. Study of the processes that shape the continents and oceans, drive the hydrologic cycle and ocean circulation, and affect climate change and the evolution of life is based on a foundation of basic mathematics, physics, and chemistry.

The need for people trained in the Earth and environmental sciences has been increasing in response to society's growing concern with sound environmental and resource management. Issues of particular concern include the impact of global climate change, the management of water resources, the development of energy and mineral resources, the disposal of waste on land and in the atmosphere and oceans, and the assessment of environmental hazards. In addition, the demand for well trained secondary school teachers of Earth sciences has been steadily increasing.

The Department of Earth Sciences offers five majors: B.S. geology, B.S. environmental sciences (interdisciplinary with the College of Life Sciences and Agriculture), B.A. Earth sciences, B.A. Earth sciences/oceanography, and B.A. Earth science teaching. These programs prepare students for advanced study in the geosciences; for entry-level professional employment in public or private institutions concerned with environmental and resource management, including consulting firms, government agencies, energy- and resource-extraction firms, utilities, and nonprofit organizations; and for secondary-school teaching of Earth sciences.

The Department of Earth Sciences also offers a minor in geology, as well as an interdisciplinary minor in oceanography.

Descriptions and requirements for the majors and minors are arranged alphabetically.

Bachelor of Arts in Earth Sciences

The bachelor of arts in Earth sciences is offered through the Department of Earth Sciences. This program provides students an opportunity to obtain a broad education and a general background in the Earth sciences with a greater degree of freedom in choosing electives than in the bachelor of science programs. By careful choice of electives, students can prepare for graduate school, business, or industry.

Requirements

1. Satisfy the general education requirements.

2. Satisfy the bachelor of arts degree requirements.

3. Complete a minimum of eight courses in the department (with a C- or better), including ESCI 401, The Dynamic Earth, or ESCI 409, Geology and the Environment; ESCI 402, Earth History; ESCI 512, Principles of Mineralogy; and five upper-level courses, two of which must be 700 or above.

4. Math requirements: 425, Calculus I, and 426, Calculus II.

It is strongly advised that students complete, as early as possible, a year each of college chemistry and physics.

Bachelor of Arts in Earth Sciences, Oceanography Option

The bachelor of arts in Earth sciences, oceanography option, is offered by the Department of Earth Sciences. This program provides students an opportunity to obtain a broad education and a general background in the Earth sciences, as well as the flexibility to choose electives in the area of oceanography. A clear, comprehensive understanding of the ocean environment will prepare students for graduate school or for employment opportunities available on our coasts in ocean-related fields such as aquaculture, fishing, tourism, environmental protection, shipping, construction, government regulation, and education.

Requirements

1. Satisfy the general education requirements.

2. Satisfy the bachelor of arts degree requirements.

3. Complete a minimum of eight courses in the department (with a C- or better) including ESCI 401, The Dynamic Earth, or ESCI 409, Geology and the Environment; ESCI 402, Earth History or ZOOL 503, Introduction to Marine Biology; ESCI 501, Introduction to Oceanography; ESCI 512, Principles of Mineralogy; and four upper-level ocean related courses, two of which must be 700 or above. Typically these would be chosen from ESCI 658, Earth, Ocean, and Atmosphere Dynamics; ESCI 750, Biological Oceanography; ESCI 752, Chemical Oceanography; ESCI 758, Physical Oceanography; and ESCI 759, Geological Oceanography.

4. Math requirements: 425, Calculus I, and 426, Calculus II.

It is strongly advised that students complete, as early as possible, a year each of college chemistry and physics.

Oceanography Minor

See the Special University Programs, Interdisciplinary Programs, and Marine Sciences sections of the catalog.

Bachelor of Arts in Earth Science Teaching

The bachelor of arts in Earth science teaching program is offered by the Department of Earth Sciences in coordination with the Department of Education. The program is specifically designed to prepare students to teach Earth sciences in secondary school. Upon graduation from this program, students are prepared to complete a masters degree in Education with an additional year of graduate study, which includes a year-long internship (EDUC 900/901). After completing this typically five-year program, students receive full teacher certification, which is recognized in most states.

Requirements

1. Satisfy the general education requirements.

2. Satisfy the bachelor of arts degree requirements.

3. Complete the following: ESCI 401, The Dynamic Earth, or ESCI 409, Geology and the Environment; ESCI 402, Earth History; ESCI 501, Introduction to Oceanography; GEOG 473, The Weather; CHEM 403-404, General Chemistry; PHYS 401-402, Introduction to Physics I and II, PHYS 406, Introduction to Modern Astronomy; plus 12 approved elective credits from intermediate and/or advanced Earth sciences courses.

4. Math requirements: 425, Calculus I, and 426, Calculus II.

5. Satisfy the secondary-school teacher education program.

General Science Certification

Students majoring in animal sciences, biochemistry, biology, Earth sciences, environmental conservation studies, environmental sciences, forestry, microbiology, plant biology, wildlife management, or zoology may seek certification to teach science at the middle, junior, or high school level.

For further information, contact the coordinator of teacher education in the Department of Education.

Bachelor of Science in Geology

The bachelor of science in geology is offered through the Department of Earth Sciences. The program represents a strong concentration in the Earth sciences and is especially well suited for students who plan to continue their studies in graduate school. Beyond a central core of courses, there is sufficient flexibility in course selection so that students may, in consultation with their academic advisers, orient the program toward a particular facet of the Earth sciences (e.g., mineralogy-petrology, oceanography, hydrogeology, geophysics-structural geology, geomorphology-glacial geology, geochemistry, paleontology-stratigraphy). Students are encouraged to attend an off-campus field camp, for which scholarship funds may be available.

Requirements

1. Satisfy the general education requirements and the bachelor of science degree requirements.

2. Satisfactorily complete MATH 425 and 426, CHEM 403-404 (or CHEM 405), PHYS 407-408, and PHYS 505 or ESCI 658. Some of these courses may also satisfy Group 2 and part of Group 3 of the general education requirements.

3. Complete a minimum of 12 courses in Earth sciences, which should include ESCI 401, The Dynamic Earth, or ESCI 409, Geology and the Environment; ESCI 402, Earth History; ESCI 501, Introduction to Oceanography; ESCI 512, Principles of Mineralogy; ESCI 614, Optical Mineralogy and Petrography; ESCI 530, Geological Field Methods; ESCI 561, Landscape Evolution; ESCI 631, Structural Geology; ESCI 652, Paleontology; and three approved earth sciences 700-level electives.

4. Complete four approved science/math electives. The following should be considered: one additional 700-level course in the Earth sciences; additional courses in mathematics, chemistry, and physics; courses in computer science, engineering, and the biological sciences; and an off-campus field camp.

Geology Minor

Any University student who is interested in Earth sciences may minor in geology. The minor consists of at least 18 semester hours, typically from five ESCI courses, each with a grade of C- or better, while maintaining a cumulative grade-point average of 2.0. A maximum of eight credits may be used for both major and minor credit. Courses include both introductory and more advanced courses. Specific course requirements are flexible to accommodate the student's interest in different facets of the geosciences. Interested students should see the Earth Sciences' undergraduate coordinator to complete an Intent to Minor form no later than their junior year.

Environmental Sciences

www.unh.edu/envsci/

(For Natural Resoures [NR] course descriptions, see page 227.)

The College of Engineering and Physical Sciences and the College of Life Science and Agriculture jointly offer a Bachelor of Science Degree in Environmental Sciences. Environmental sciences is an interdisciplinary field concerned with the interaction of biological, chemical, and physical processes that shape the natural environment. Students graduating with a degree in Environmental Sciences will have an understanding of these interacting processes, the ability to effectively communicate with both scientific and lay audiences, competency in field methods appropriate for entry-level environmental science positions, competency in the use and application of geographic information systems (GIS), a basic understanding of environmental policy, and the ability to contribute to multidisciplinary teams. The University of New Hampshire is a recognized leader in environmental sciences research, and the environmental sciences program capitalizes on faculty expertise in this area. The program has 12 full-time faculty members, with major teaching and research emphases in the areas of biogeochemical cycling, environmental chemistry, ecosystem science, global change, hydrology, plant ecology, soil science, and water resource management. Employment opportunities include: environmental consulting firms, educational facilities (e.g., science centers), environmental monitoring laboratories (e.g., water treatment plants; the Environmental Protection Agency), government agencies (e.g., the U.S. Geological Survey, Bureau of Land Management, Natural Resource Conservation Service), university and government research laboratories, and nongovernment environmental organizations. The environmental sciences program also constitutes an excellent preparation for graduate programs in several areas relating to the environment. Students should consult with their adviser early if their goals include further study.

Requirements

In addition to general education requirements, all students will take Introduction to Environmental Science (NR 403) and Professional Perspectives in Natural Resources (NR 400), plus one other elective introductory environmental science course. Foundation courses include two semesters of chemistry (CHEM 403, 404) and calculus (MATH 425, 426), one semester of geology (ESCI 401, 402, or 409), one semester of statistics (MATH 644 or BIOL 528), one semester of physics (PHYS 407) and one approved biology course. Core courses include Techniques in Environmental Sciences (ESCI 534), Introduction to GIS (NR

658), Fate and Transport in the Environment (ESCI 654), Natural Resource and Environmental Policy (NR 602), and a capstone course sequence NR 791 and 792).

Students must complete an additional eight courses in one of the following options:

Hydrology
PHYS 408, General Physics II
ESCI 561, Landscape Evolution
NR 501, Introduction to Soil Sciences, or ESCI 512, Principles of Mineralogy
NR 604, Watershed Hydrology
ESCI 705, Principles of Hydrology
ESCI 710, Groundwater Hydrology
Two approved electives

Soil and Watershed Management
PHYS 408, General Physics II
NR 501, Introduction to Soil Sciences
NR 604, Watershed Hydrology
NR 703, Watershed Water Quality Management
NR 706, Soil Ecology
Three approved electives

Ecosystems
NR 527, Forest Ecology, or BIOL 541, General Ecology
NR 730, Terrestrial Ecosystems
NR 751, Aquatic Ecosystems
NR 765, Community Ecology
Four approved electives

For a list of approved elective courses and for further information about the major, contact the program coordinator, John D. Aber, Department of Natural Resources and the Environment, 102 Nesmith Hall, (603) 862-3045; john.aber@unh.edu.

Electrical and Computer Engineering (ECE)

www.ece.unh.edu/

(For course descriptions, see page 181.)

Chairperson: John R. LaCourse

Professor: Kent A. Chamberlin, Christian P. De Moustier, L. Gordon Kraft, John R. LaCourse, W. Thomas Miller III, Andrzej Rucinski, Kondagunta U. Sivaprasad

Associate Professor: Michael J. Carter, Allen D. Drake, Andrew L. Kun, Richard A. Messner

Research Associate Professor: Brian P. Calder

Affiliate Associate Professor: Charles H. Bianchi, Thaddeus P. Kochanski, Barbara Kraft, Paul W. Latham II, William H. Lenharth, Timothy Paek, Henk A.E. Spaanenburg

Assistant Professor: Kuan Zhou

Instructor: Francis C. Hludik Jr.

Lecturer: Wayne J. Smith

The Department of Electrical and Computer Engineering offers a B.S. in electrical engineering and a B.S. in computer engineering. Both degree programs are accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (401) 347-7700.

ECE Department Mission

The mission of the department is to foster and advance knowledge in electrical and computer engineering.

The mission involves:

• teaching courses in electrical and computer engineering and related fields at the bachelor's, master's and doctoral levels;

• advancing knowledge through research and scholarship;

• serving the state and nation by making the department's intellectual resources available to industry and government agencies.The undergraduate EE and CE programs shall provide a firm foundation in electrical and computer engineering theory and practice, with a mix of laboratory and design experiences. The programs also shall foster teamwork and project management skills.

The graduate ECE program shall lead to the degrees of master of science in electrical engineering and the doctor of philosophy in electrical engineering. Research and scholarship are core components of the department's mission and they directly impact undergraduate and graduate education. Success in obtaining funds to procure equipment and support research efforts is therefore an essential objective for the department.

The department recognizes the need to conduct periodic reviews and adjustments to meet the current and projected needs of the state and nation according to its mission objectives. The current mission was approved by the ECE faculty in March 2001, approved by the ECE Student Advisory Board in October 2001, and ratified by the ECE Industrial Advisory Board in April 2002. The mission was reaffirmed by the ECE Industrial Advisory Board on November 22, 2004.

Electrical Engineering and Computer Engineering Program Educational Objectives

The Department of Electrical and Computer Engineering has adopted a set of program educational objectives made up of statements describing the expected accomplishments of graduates during the first several years following graduation from either program:

• graduates will function at a technically outstanding level in formulating and solving problems;

• graduates will produce competent written and oral reports, and provide project management and leadership;

• through a thorough grounding in engineering fundamentals, graduates will be prepared for a successful engineering career amid future technological changes;

• through a well-rounded education, graduates are able to respond to changing career paths, to maintain an interest in lifelong learning, and to advance professionally;

• graduates will be creative when dealing with contemporary issues facing society in local, global, historical, social, economic, and political contexts in relation to electrical and computer engineering;

• graduates will be able to design, prototype, and test electrical and computer engineering designs using state-of-the-art test equipment in a laboratory environment.

The electrical and computer engineering educational program objectives were approved by the ECE faculty in March 2001, approved by the ECE Student Advisory Board in November 2001, and ratified by the ECE Industrial Advisory Board in March 2002. Program educational objectives were reaffirmed by the ECE Industrial Advisory Board on November 22, 2004.

Electrical Engineering and Computer Engineering Program Educational Outcomes

The Department of Electrical and Computer Engineering has adopted a set of program educational outcomes made up of statements describing what students are expected to know and are able to do by the time of graduation, the achievement of which indicates that the student is equipped to achieve the program objectives. The current electrical engineering program educational outcomes and computer engineering program educational outcomes are:

• 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;

• an ability to function on multidisciplinary teams;

• an ability to identify, formulate, and solve engineering problems;

• an ability to communicate effectively;

• an understanding of professional and ethical responsibility;

• the broad education necessary to understand the impact of engineering solutions in a global and societal context;

• a recognition of the need for, and ability to engage in, lifelong learning;

• a knowledge of contemporary issues;

• an ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

Electrical and computer program educational outcomes were approved by the ECE faculty in March 2001, approved by the ECE Student Advisory Board in October 2001, and ratified by the ECE Industrial Advisory Board in March 2002. The program educational outcomes were reaffirmed by the ECE Industrial Advisory Board on November 22, 2004.

Students contemplating a decision between the electrical engineering and computer engineering degree programs should consider both the similarities and differences of the two programs. The two curricula require the same foundational courses in mathematics, physics, analog and digital electronic circuits, and a capstone senior design project. The computer engineering degree program requires additional fluency in software development and advanced computer system and hardware design. The electrical engineering degree program requires advanced study in analog and mixed-signal electronic circuit and system analysis and design. The University's general education requirements are identical for both degree programs.

Electrical Engineering Program

Electrical engineers design, develop, and produce the electrical and electronic systems upon which modern society has come to depend: basic infrastructure, such as the electric power grid and fiber optic communication lines; public conveniences, such as mag lev transporters and LED signs; consumer products, such as iPods and MP3 players; personal communication devices, such as cell phones and BlackBerry© devices; military systems, such as rail guns and laser weapons; instruments that can image the ocean floor or analyze the Earth's atmosphere from satellites; and medical diagnostic machines like CAT and MRI scanners. Almost every facet of modern life is touched by the work of electrical engineers.

At UNH, the cornerstone of the electrical engineering program is the involvement of students in the solution of real-world problems. Students electing this major gain knowledge of advanced electronic circuit and system design through the use of computer-aided design tools, hardware circuit prototyping, and hands-on laboratory testing.

In addition to general University requirements, the department has a number of grade-point average and credit requirements.

1. For an electrical engineering major to enter the junior year and take any of the first-term junior courses (ECE 544, 617, 633, or 651), he or she must have taken, and achieved a cumulative grade-point average of 2.1 in all of the following freshman and sophomore courses: MATH 425, 426, 527; PHYS 407, 408; and ECE 541, 543, 548, and 562.

2. Any electrical engineering major whose cumulative grade-point average in ECE courses is less than 2.0 during any three semesters will not be allowed to continue as an electrical engineering major.

3. Electrical engineering majors must achieve a 2.0 grade-point average in ECE courses as a requirement for graduation.

To make an exception to any of these departmental requirements based on extenuating circumstances, students must petition the department's undergraduate committee. Mindful of these rules, students, with their advisers' assistance, should plan their programs based on the distribution of courses in the following chart for a total of at least 133 credits.

Freshman Year	**Fall**	**Spring**
ECE 401, Perspectives in Electrical & Computer Engineering	4	-
MATH 425, Calculus I	4	-
CS 410, Introduction to Scientific Programming**	4	-
CHEM 405, General Chemistry	4	-
PHYS 407, Physics I	-	4
ENGL 401, First-Year Writing	-	4
MATH 426, Calculus II	-	4
General Education Elective**	-	4
Total	**16**	**16**

Sophomore Year	**Fall**	**Spring**
ECE 541, Electrical Circuits	4	-
ECE 543, Introduction to Digital Systems	4	-
PHYS 408, Physics II	4	-
MATH 527, Differential Equations with Linear Algebra	4	-
ECE 548, Electronic Design I	-	4
ECE 562, Computer Organization	-	4
ME 523, Introduction to Statics and Dynamics	-	3
General Education Elective	-	4
Total	**16**	**15**

Junior Year	**Fall**	**Spring**
ECE 544, Engineering Analysis	4	-
ECE 617, Junior Lab I	4	-
ECE 633, Signals and Systems I	3	-
ECE 651, Electronic Design II	4	-
General Education Elective	4	-
ECE 603, Electromagnetic Fields & Waves	-	4
ECE 618, Junior Laboratory II	-	4
ECE 634, Signals and Systems II	-	3
ECE 647, Random Processes and Signals in Engineering	-	3
ECE 668, Fundamentals of Computer Engineering	-	4
ECE 694, Engineering Professional Principles	-	1
Total	**19**	**19**

Senior Year	**Fall**	**Spring**
Professional Elective*	4	-
Professional Elective*	4	-
General Education Elective	4	-
General Education Elective	4	-
ECE 791 Senior Project I	2	-
Professional Elective*	-	4
Professional Elective*	-	4
General Education Elective	-	4
ECE 792, Senior Project II	-	2
Total	**18**	**14**

*Professional electives normally consist of 700-level ECE courses. Each course must carry at least three credits, and no more than one can be an independent study, special topics, or a project course. An alternative is a student-designed plan approved by the ECE undergraduate committee.

**Students who wish to preserve the option of transferring to the computer engineering major without incurring a delay in graduation should consult with their academic adviser before electing these courses. It is recommended that such students take CS 415, Introduction to Computer Science I, in the fall semester and CS 416, Introduction to Computer Science II, in the spring semester in place of the listed courses.

Computer Engineering Program

Computers have become embedded in virtually every engineering system. Computer engineering, traditionally a subset of electrical engineering, is a rapidly growing field that emphasizes the design, interfacing, hardware/software tradeoffs, and real-time applications of computers. Students who elect this major will gain a knowledge of both hardware and software concepts, and will learn to design, build, and test systems containing digital computers.

In addition to general University requirements, the department has a number of grade-point average and credit requirements.

1. For a computer engineering major to enter the junior year and take any of the first-term junior courses (ECE 541, 544, 633), he or she must have taken, and achieved a cumulative grade-point average of 2.1 in, all of the following freshman and sophomore courses: MATH 425, 426, 527; PHYS 407, 408; CS 415, 416, 515, 516; and ECE 543, 562, and 583.

2. Any computer engineering major whose cumulative grade-point average in ECE and CS courses is less than 2.0 during any three semesters will not be allowed to continue as a computer engineering major.

3. Computer engineering majors must achieve a 2.0 grade-point average in ECE courses as a requirement for graduation.

To make an exception to any of these departmental requirements based on extenuating circumstances, students must petition the department's undergraduate committee. Mindful of these rules, students, with their advisers' assistance, should plan their programs based on the distribution of courses in the chart below for a total of at least 131 credits.

Freshman Year	Fall	Spring
ECE 401, Perspectives in Electrical & Computer Engineering	4	-
MATH 425, Calculus I	4	-
CS 415, Intro to Computer Science I	4	-
General Education Elective	4	-
ECE 543, Intro to Digital Systems	-	4
MATH 426, Calculus II	-	4
CS 416, Intro to Computer Science II	-	4
ENGL 401, First-Year Writing	-	4
Total	**16**	**16**

Sophomore Year	Fall	Spring
ECE 562 Computer Organization	4	-
PHYS 407, Physics I	4	-
MATH 527, Differential Equations with Linear Algebra	4	-
CS 515, Data Structures	4	-
ECE 583, Design with Programmable Logic	-	4
PHYS 408, Physics II	-	4
CS 516, Software Design & Development	-	4
General Education Elective	-	4
Total	**16**	**16**

Junior Year	Fall	Spring
ECE 541, Electrical Circuits	4	-
ECE 544, Engineering Analysis	4	-
ECE 633, Signals and Systems I	3	-
General Education Elective	4	-
ECE 548, Electronic Design I	-	4
ECE 603, Electromagnetic Fields and Waves	-	4
ECE 647, Random Processes & Signals in Engineering	-	3
ECE 649, Embedded Microcomputer Based Design	-	4
ECE 694, Engineering Professional Principles	-	1
Total	**15**	**16**

Senior Year	Fall	Spring
Professional Elective*	4	-
ECE 734, Network Data Communications	4	
ECE 714, Intro to Digital Signal Processing	4	-
General Education Elective	4	-
ECE 791, Senior Project I	2	-
Professional Elective*	-	4
Professional Elective*	4	-
General Education Elective	-	4
ECE 792, Senior Project II	-	2
General Education Elective	-	4
Total	**18**	**18**

* Three professional electives must be selected from the following categories of courses:

At least one from: ECE 711, ECE 715, ECE 717

No more than one from: ADMIN 640, DS 773, DS 774

Any of these: ECE 634, ECE 651, ECE 7XX, CS 620, CS 645, CS 659, CS 671, CS 7XX

Environmental Engineering (ENE)

www.unh.edu/environmental-engineering/

(For course descriptions, see page 189.)

Professor: Dale P. Barkey, Russell T. Carr, M. Robin Collins, Ihab H. Farag, Nancy E. Kinner, James P. Malley Jr. , Virendra K. Mathur, Palligarnai T. Vasudevan

Research Professor: T. Taylor Eighmy

Associate Professor: Thomas P. Ballestero, Kevin H. Gardner, Nivedita R. Gupta, Jennifer M. Jacobs

Research Assistant Professor: Jeffrey S. Melton, Robert M. Roseen

The College of Engineering and Physical Sciences offers a bachelor of science degree in environmental engineering (ENE) and an interdisciplinary minor in environmental engineering.

The bachelor of science degree in environmental engineering is accredited by the engineering accreditation commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

Mission

The environmental engineering program offers an undergraduate degree in environmental engineering that prepares students for productive careers in the public and private sectors and for graduate studies. The program emphasizes fundamental principles in environmental engineering and design, built upon a strong base of chemistry, physics, mathematics, and engineering science. The program prepares students to work in multidisciplinary teams that analyze, formulate, and communicate sustainable solutions to complex environmental problems. The importance of developing sustainable solutions that provide economic, social, and environmental benefits to society is emphasized. The program instills in its students an appreciation for the responsibilities engineers have to society and teaches them the skills necessary to continue learning and improving their professional expertise throughout their careers.

The ENE degree program provides an opportunity for students to specialize in industrial or municipal processes. The curriculum prepares students to plan and design systems to minimize the impact of human activity on the environment and protect human health.

Educational Objectives

ENE program graduates will have the skills, experience, and knowledge to pursue successful careers as environmental engineers. They also will have demonstrated the ability to identify information needs; locate information resources and/or design laboratory or field experiments to attain required information; and evaluate and synthesize data with sound engineering principles, methodologies, and the latest technology into creative, sustainable, safe, and economical engineering solutions to environmental engineering problems. The solutions they develop will minimize the impact of human activities on the environment and protect human health. Program graduates will have a foundation for advanced studies in environmental engineering and oral and written communication skills that will enable them to clearly explain engineering options and recommend solutions to stakeholders. ENE program graduates will have demonstrated in-depth knowledge within environmental engineering and an awareness of potential social, economic, political, and environmental impacts of engineering practices. They will have an appreciation of the contribution of environmental engineers to the benefit of society and the responsibilities of a professional environmental engineer. They will work as part of multidisciplinary teams to arrive at solutions to environmental engineering problems. ENE program graduates will be prepared to obtain professional engineering licensure; have the capacity to continue learning and improving their professional expertise and skills by participating in professional associations, conferences, workshops and courses; and understand the importance of continued professional development.

At the end of the sophomore year, students are required to have a minimum overall grade-point average of 2.0 and a grade-point average of 2.0 in all mathematics, physics, chemistry, and engineering courses to be permitted to enroll in junior-level courses. To qualify for graduation, an ENE major must: have satisfied the previously specified course requirements, have satisfied the University's general education requirements, have a minimum cumulative grade-point average of 2.0, and have a minimum grade-point average of 2.0 in engineering courses.

Bachelor of Science in Environmental Engineering-Industrial Processes (IP) Emphasis

The industrial processes (IP) emphasis of environmental engineering is a process-based program that draws on the principles of chemistry, physics, mathematics, and engineering sciences. Due to the complex nature of many aspects of environmental pollution, a broad understanding of the fundamentals

of engineering and sciences forms the most desirable preparation for a career in the environmental field. The program is designed to provide training not only for end-of-pipe pollution control technologies, but also for expertise in process engineering and process design, essential for achieving the objectives of pollution curtailment and prevention. Such training is especially valuable in resolving industrial pollution problems. Career opportunities for environmental engineers with this background are found in industry, research institutes, government agencies, teaching, and consulting practice. Students may also enter graduate study at the M.S. or Ph.D. levels.

Engineering design is a critical aspect of the IP curriculum. In order to meet the objective of producing creative, problem-solving engineers, design concepts are introduced early in the curriculum and design experience is integrated into every engineering course. Students learn to seek optimal solutions to open-ended problems and function in design-based team projects. Design ability is finally demonstrated at the end of the capstone course (ENE 708), when self-directed teams develop a comprehensive design report for a full-scale engineering process based on a national process design competition problem.

Since 1993, the program faculty has administered a pollution prevention internship program with industries in New Hampshire, Maine, and Massachusetts, initially funded by U.S. EPA and NHDES. In the past 12 years, the program has served more than 40 facilities. Each year about 12 students have enrolled in the pollution prevention internship program, which provides hands-on industrial employment for 10 weeks during the summer assisting industry with projects in process modification, material substitution, chemical re-use, risk assessment, safety, and economic analysis. The program faculty also assisted NHDES in setting up instrumentation in the Seacoast region of New Hampshire to monitor the precursor of ozone formation.

The B.S. program requires a minimum of 132 credits for graduation and can be completed in four years. There are nine electives in the curriculum: six for the fulfillment of the University's general education requirements and the remaining three for technical electives to be chosen from the specified elective course list. Due to the substantial overlap in course requirements for the environmental engineering IP and chemical engineering majors, students will be able to transfer between these two programs during the first three semesters without losing any course credits toward graduation.

Suggested Technical Electives	**Credits**
CHE 602, Heat Transfer and Unit Operations	3
CHE 707, Chemical Engineering Kinetics	3
CHE 744, Corrosion	4
ENE 739, Industrial Wastewater Treatment	3
ENE 746, Bioenvironmental Engineering Design	4
ENE 747, Introduction to Marine Pollution	3
CIE 766, Introduction to Geo-Environmental Engineering	3
ESCI 409, Geology and the Environment	4
ESCI 561, Landscape Evolution	4
ESCI 705, Principles of Hydrology	4
ESCI 715, Global Atmospheric Chemistry	3
MICRO 503, General Microbiology	5

First Year	**Fall**	**Spring**
CHEM 405, General Chemistry	4	-
MATH 425-426, Calculus I & II	4	4
PHYS 407, General Physics I	-	4
ENGL 401, First-Year Writing	4	-
ENE 400, Environmental Engineering Lectures I	1	-
ENE 401, Environmental Engineering Lectures II	-	1
General Education Electives	-	8
MICR 501, Microbes in Human Disease	4	-
Total	**17**	**17**
Second Year	**Fall**	**Spring**
CHE 501-502, Introduction to Chemical Engineering I & II	3	3
CHEM 683-684, Physical Chemistry I & II	3	3
CHEM 685, Physical Chemistry Lab I	2	-
MATH 527, Differential Equations	4	-
PHYS 408, General Physics II	4	-
CS 410, Introduction to Scientific Programming	-	4
General Education Electives	-	8
Total	**16**	**18**
Third Year	**Fall**	**Spring**
CHE 601, Fluid Mechanics and Unit Operations	3	-
CHE 604, Chemical Engineering Thermodynamics	-	4
ENE 612, Unit Operations Lab II	-	3
CHEM 651-652, Organic Chemistry I & II	3	3
CHEM 653, Organic Chemistry Lab I	2	-
ENE 742, Solid and Hazardous Waste Engineering	3	-
MATH 644, Statistics for Engineers & Scientists	4	-
General Education and Technical Electives	-	7-8
Total	**15**	**17-18**
Fourth Year	**Fall**	**Spring**
CHE 703, Mass Transfer and Stagewise Operations	3	-
ENE 708, Industrial Process Design	-	4
ENE 709, Fundamentals of Air Pollution and Control	4	-
ENE 713, Unit Operations Lab II	3	-
ENE 752, Process Dynamics and Control	-	4
ENE 772, Physicochemical Processes for Water/Air Quality	-	4
ESCI 710, Groundwater Hydrology	-	4
Technical Electives	6-8	-
Total	**16-18**	**16**

Bachelor of Science in Environmental Engineering-Municipal Processes (MP) Emphasis

Environmental engineers graduating from the municipal processes (MP) emphasis will plan, design, and construct public and private facilities to minimize the impact of human activity on the environment and to protect human health. For example, environmental engineers with a municipal processes perspective design and build drinking water treatment systems, municipal and industrial wastewater treatment plants, solid waste management facilities, contaminated ground water remediation systems, and hazardous waste remediation facilities. These facilities must meet regulatory requirements, be cost-effective to build and maintain, be safe to operate, and have minimal environmental impact.

In ENE 400 and 401, students are introduced to the full spectrum of environmental engineering projects that they will subsequently explore in design teams during their degree program. As part of these experiences, students visit and tour field sites, and interact with engineers who have been involved in the design and/or construction of the projects. Design is integrated throughout the curriculum, and particularly emphasized in junior- and senior-level courses. As part of these projects, students analyze treatment alternatives, recommend a system that meets regulatory operational needs, and prepare an implementation schedule and project budget. Detailed design projects are performed in ENE 744 and 746. ENE 788 serves as a capstone design experience where students work on a multi-interdisciplinary environmental engineering project as part of the U.S. Department of Energy's international WERC competition held in New Mexico every April, and apply skills learned in other courses while working with real-world clients.

The following schedule is a sample of a planned program for environmental engineering students completing the major within the municipal processes emphasis.

First Year	**Fall**	**Spring**
ENE 400, 401, Environmental Engineering Lectures I, II	1	1
ENGL 401, First-Year Writing	4	-
MATH 425, 426, Calculus I, II	4	4
General Education Electives*	4	4
CHEM 405, General Chemistry	4	-
PHYS 407, General Physics I	-	4
ENGL 502, Technical Writing	-	4
Total	**17**	**17**

Second Year	Fall	Spring
ENE 520, Environmental Pollution and Protection	4	-
ENE 521, Environmental Engineering Seminar	-	1
CIE 525, Statics	3	-
MATH 527, Differential Equations with Linear Algebra	4	-
MATH 644, Statistics for Engineers and Scientists	-	4
CHEM 545, Organic Chemistry Lecture	3	-
CHEM 546, Organic Chemistry Laboratory	2	-
CIE 533, Project Engineering	-	3
TECH 564, Fundamentals of CAD	-	3
General Education Elective*	-	4
Total	**16**	**15**

Third Year	Fall	Spring
CIE 642, Fluid Mechanics	4	-
Technical Elective**	4	-
ENE 645, Fundamental Aspects of Environmental Engineering	-	4
ENE 756, Environmental Engineering and Microbiology	-	4
ENE 742, Solid and Hazardous Waste Engineering	3	-
Engineering Lab Elective**	-	4
Hydraulics Elective**	-	3-4
General Education Elective*	4	-
Total	**15**	**15/16**

Summer	Credits
Environ Engineering Experience† (ENE 696 or 697)	1-2

Fourth Year	Fall	Spring
ENE 746, Bioenvironmental Engineering Design	4	-
General Education Elective*	4	-
Environmental Engineering Elective**	3-4	6-8
ENE 744, Physicochemical Treatment Design	-	4
ENE 788, Project Planning and Design	-	3
ESCI 710, Groundwater Hydrology	-	4
ENE 784, Intro to Project Planning & Design	1	-
ENE 749, Water Chemistry	4	-
Total	**16/17**	**17/19**

*See general education requirements.

**Approved lists of technical, hydraulics, engineering laboratory, and ENE design and non-design electives are available from the ENE undergraduate coordinator. Students must take a minimum of three 700-level ENE electives totaling at least 10 credits. One ENE elective course must be from the design category.

†During one summer, majors who have a job at an approved level in the environmental engineering field performing an approved internship in environmental engineering or conducting a research project under the supervision of a faculty member are able to register for ENE 696 or 697. A student may receive a one-credit field experience or up to two credits for an environmental engineering internship. The internship could be used as an environmental engineering elective, but this would require approval of the faculty.

The municipal processes emphasis of the ENE program requires a minimum of 128 total credits for graduation.

Environmental Engineering Minor

The environmental engineering minor is intended primarily for students in engineering and physical sciences, who are not in the chemical, civil, or environmental engineering degree programs. Students contemplating such a minor should plan on a strong background in the sciences and mathematics (including differential equations).

The minor provides a comprehensive introduction to major areas of interest in environmental protection—namely, air pollution and water pollution—through the three required courses. Further breadth in environmental engineering or depth in specific areas can be attained through the choice of appropriate elective courses.

The minor requires a minimum of five courses, as follows: 1) three required courses: ENE 645, Fundamental Aspects of Environmental Engineering; ENE 709, Fundamentals of Air Pollution and Its Control; and ENE 772, Physicochemical Processes for Water and Air Quality Control, or ENE 743, Environmental Sampling and Analysis; 2) a minimum of two elective ENE courses.

Choice of elective courses should be made in consultation with the minor area adviser, James P. Malley, civil engineering, or Dale P. Barkey, chemical engineering. Students normally start this program in the junior year and should declare their intention to enter the program as early as possible during the sophomore year. During the final semester, students must apply to the dean to have the minor appear on the transcript.

International Affairs (dual major)

(For course descriptions, see page 207.)

For program description, see Special University Programs, page 116.

Mathematics and Statistics (MATH)

www.math.unh.edu

(For course descriptions, see page 216.)

Professor: Liming Ge, Karen J. Graham, Eric L. Grinberg, Donald W. Hadwin, Rita A. Hibschweiler, A. Robb Jacoby, Ernst Linder, Dmitri A. Nikshych, Samuel D. Shore, Kevin M. Short, Marianna A. Shubov

Associate Professor: Maria Basterra, David V. Feldman, Edward K. Hinson, Linyuan Li, Sharon M. McCrone

Assistant Professor: Timothy P. Fukawa-Connelly, Mark Lyon, Junhao Shen

Instructor: Philip J. Ramsey

Lecturer: Adam Boucher, Mehmet Orhon, Neil Portnoy, Yitang Zhang

The Department of Mathematics and Statistics offers a variety of programs. These programs provide flexibility through elective choices and are designed to maximize educational and employment opportunities. Each student must enroll in one specific program; however, changes between programs usually can be accommodated.

The first two years of all programs are similar. In the first year, students are expected to take Calculus I (MATH 425) and Calculus II (MATH 426) as well as an introductory scientific programming course (CS 410). A sophomore typically takes follow-up calculus courses in differential equations (MATH 527) and multidimensional calculus (MATH 528), an introductory statistics course (MATH 539), and a course in mathematical proof (MATH 531).

In addition to its degree programs, the department has an active interest in the actuarial profession and is an examination center for the Society of Actuaries. Those interested in actuarial science should seek the advice of the coordinator of the actuarial program in the department.

For more information about the department's undergraduate programs, visit www.math.unh.edu.

Standards for Graduation

To be certified for graduation with a degree from the Department of Mathematics and Statistics, a student must complete all courses used to satisfy the requirements for the major program with a grade of C- or better and have an overall grade-point average of at least 2.0 in these courses.

Bachelor of Arts, Mathematics Major

This program may offer a broader liberal arts program than the bachelor of science degree programs. By a careful selection of electives, students can shape this major into a preparation for graduate school, business, or industry.

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527*, Differential Equations with Linear Algebra
MATH 528*, Multidimensional Calculus
MATH 531, Mathematical Proof,
or MATH 545, Introduction to Linear Algebra and Mathematical Proof
MATH 539, Introduction to Statistical Analysis
MATH 761, Abstract Algebra
MATH 762, Linear Algebra
MATH 767, One-Dimensional Real Analysis
Two approved MATH electives chosen in consultation with the academic adviser

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required courses
CS 410, Introduction to Scientific Programming

Foreign language requirement
Foreign language requirement as defined by the University for the B.A. degree

Bachelor of Science in Mathematics

This program offers the strongest concentration in mathematics, requiring courses that are intended to prepare the student for graduate work in mathematics. Through a judicious choice of electives, students may design stronger pre-graduate programs, a program in applied mathematics, or slant the program toward a career in business or industry.

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527*, Differential Equations with Linear Algebra
MATH 528*, Multidimensional Calculus
MATH 531, Mathematical Proof,
or MATH 545, Introduction to Linear Algebra and Mathematical Proof
MATH 539, Introduction to Statistical Analysis
MATH 761, Abstract Algebra
MATH 762, Linear Algebra
MATH 767, One-Dimensional Real Analysis
MATH 784, Topology
MATH 788, Complex Analysis
Two approved MATH electives chosen in consultation with the academic adviser
*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required courses
CS 410, Introduction to Scientific Programming
PHYS 407-408, General Physics I and II, which may be used to satisfy general education requirements in Group 3

Bachelor of Science: Interdisciplinary Programs in Mathematics and Its Applications

The programs in interdisciplinary mathematics prepare students for employment in areas of applied mathematics and statistics. Some of them can lead to graduate work in appropriate fields (e.g., physics, computer science, or economics). The major may consist of mathematics combined with:

computer science,
economics,
electrical science,
physics, or
statistics.

Each program requires 10 mathematics courses along with at least six courses in the discipline of the option. Specific requirements for each option are given in the following listing.

Computer Science Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527,* Differential Equations with Linear Algebra
MATH 528,* Multidimensional Calculus
MATH 531, Mathematical Proof
MATH 532, Discrete Mathematics
MATH 539, Introduction to Statistical Analysis
MATH 645,* Linear Algebra for Applications
MATH 753, Introduction to Numerical Methods I
One approved MATH elective chosen in consultation with the academic adviser

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required CS courses
CS 415, Introduction to Computer Science I
CS 416, Introduction to Computer Science II
CS 515, Data Structures
CS 516, Introduction to Software Design and Development
CS 520, Assembly Language Programming and Machine Organization
CS 620, Operating System Fundamentals
One course chosen in consultation with the academic adviser from the following:
CS 645, Intro. to Formal Specification and Verification
CS 659, Intro. to the Theory of Computation
One approved CS elective chosen in consultation with the academic adviser

Economics Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527,* Differential Equations with Linear Algebra
MATH 528,* Multidimensional Calculus
MATH 531, Mathematical Proof
MATH 539, Introduction to Statistical Analysis
MATH 645,* Linear Algebra for Applications
MATH 739, Applied Regression Analysis
One MATH courses chosen in consultation with the academic adviser from the following:
MATH 740, Design of Experiments I
MATH 741, Survival Analysis
MATH 742, Multivariate Statistical Methods
MATH 755, Probability and Stochastic Processes with Applications
One approved MATH elective chosen in consultation with the academic adviser

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required courses
CS 410, Introduction to Scientific Programming
ECON 401, Principles of Economics (Macro)
ECON 402, Principles of Economics (Micro)
ECON 605, Intermediate Microeconomic Analysis
ECON 611, Intermediate Macroeconomic Analysis
ECON 726, Introduction to Econometrics
One approved ECON or DS course chosen in consultation with the academic adviser

Electrical Science Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527,* Differential Equations with Linear Algebra
MATH 528,* Multidimensional Calculus
MATH 531, Mathematical Proof
MATH 539, Introduction to Statistical Analysis
MATH 645,* Linear Algebra for Applications
MATH 646, Introduction to Partial Differential Equations
MATH 647, Complex Analysis for Applications
MATH 753, Introduction to Numerical Methods I

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required courses
CS 410, Introduction to Scientific Programming
ECE 541, Electrical Circuits
ECE 548, Electronics Design I
ECE 603, Electromagnetic Fields and Waves I
ECE 633, Signals and Systems I
ECE 634, Signals and Systems II
ECE 757, Fundamentals of Communication Systems

Physics Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527,* Differential Equations with Linear Algebra
MATH 528,* Multidimensional Calculus
MATH 531, Mathematical Proof
MATH 539, Introduction to Statistical Analysis
MATH 645,* Linear Algebra for Applications
MATH 646, Introduction to Partial Differential Equations
MATH 647, Complex Analysis for Applications
MATH 753, Introduction to Numerical Methods I

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required courses
CS 410, Introduction to Scientific Programming
PHYS 407, General Physics I
PHYS 408, General Physics II
PHYS 505-506, General Physics III
PHYS 615, Classical Mechanics and Mathematical Physics I
PHYS 616, Classical Mechanics and Mathematical Physics II

Two PHYS courses, chosen in consultation with the academic adviser from the following:
PHYS 508, Thermodynamics and Statistical Mechanics
PHYS 701, Introduction to Quantum Mechanics I
PHYS 702, Introduction to Quantum Mechanics II
PHYS 703, Electricity and Magnetism I
PHYS 704, Electricity and Magnetism II
PHYS 708, Optics

Statistics Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527,* Differential Equations with Linear Algebra
MATH 528,* Multidimensional Calculus
MATH 531, Mathematical Proof
MATH 539, Introduction to Statistical Analysis
MATH 645,* Linear Algebra for Applications
MATH 739, Applied Regression Analysis
MATH 755, Probability and Stochastic Processes with Applications
MATH 756, Principles of Statistical Inference

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Other required courses
CS 410, Introduction to Scientific Programming
Two MATH courses chosen in consultation with the academic adviser from the following:
MATH 740, Design of Experiments I
MATH 741, Survival Analysis
MATH 742, Multivariate Statistical Methods
Three approved MATH electives chosen in consultation with the academic adviser

Bachelor of Science in Mathematics Education

This professional degree program prepares students for mathematics teaching at the elementary, middle/junior high, or secondary level. The program is coordinated with the education department's teacher certification programs. For the elementary option, full certification requires the five-year program. Students may complete the degree requirements for middle/junior high or secondary option with full teacher certification in either four or five years. Students electing the four-year option must plan for one semester of student teaching (EDUC 694) in their senior year and must consult with the departmental adviser in order to accommodate the scheduling of required MATH courses. The five-year program requires a year-long teaching internship in the fifth year that can be coupled with other graduate work leading to a master's degree. See education, College of Liberal Arts, page 35.

Elementary School Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 539, Introduction to Statistical Analysis
MATH 545, Introduction to Linear Algebra and Mathematical Proof
MATH 619, Historical Foundations of Mathematics
MATH 621, Number Systems for Teachers
MATH 622, Geometry for Teachers
MATH 623, Topics in Mathematics for Teachers
MATH 657, Geometry
MATH 700, Introduction to Mathematics Education
MATH 703, The Teaching of Mathematics, K-6
Two approved MATH elective chosen in consultation with the academic adviser

Other required courses
CS 410, Introduction to Scientific Programming
PHYS 406, Introduction to Modern Astronomy, which may be used to satisfy general education requirements in Group 3
EDUC 500, Exploring Teaching
EDUC 700, Educational Structure and Change
EDUC 701, Human Development and Learning: Educational Psychology
EDUC 705, Alternative Perspectives on the Nature of Education
EDUC 706, Introduction to Reading In the Elementary Schools

Note: EDUC 703F, EDUC 703M and EDUC 751 are requirements for certification that may be taken as an undergraduate.

Middle/Junior High School Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 539, Introduction to Statistical Analysis
MATH 545, Introduction to Linear Algebra and Mathematical Proof
MATH 619, Historical Foundations of Mathematics
MATH 621, Number Systems for Teachers
MATH 622, Geometry for Teachers
MATH 623, Topics in Mathematics for Teachers
MATH 657, Geometry
MATH 698, Senior Seminar
MATH 700, Introduction to Mathematics Education
MATH 780, Teaching of Mathematics, 5-8
Two approved MATH elective chosen in consultation with the academic adviser

Other required courses
CS 410, Introduction to Scientific Programming
EDUC 500, Exploring Teaching
EDUC 700, Educational Structure and Change
EDUC 701, Human Development and Learning: Educational Psychology
EDUC 705, Alternative Perspectives on the Nature of Education

Note: EDUC 751 is a requirement for certification that may be taken as an undergraduate.

Secondary School Option

Required MATH courses
MATH 425, Calculus I
MATH 426, Calculus II
MATH 527, Differential Equations with Linear Algebra
MATH 528, Multidimensional Calculus
MATH 539, Introduction to Statistical Analysis
MATH 545, Introduction to Linear Algebra and Mathematical Proof
MATH 619, Historical Foundations of Mathematics
MATH 624, Analysis for Secondary School Teachers
MATH 657, Geometry
MATH 698, Senior Seminar
MATH 761, Abstract Algebra
MATH 700, Introduction to Mathematics Education
MATH 791, Teaching of Mathematics, 7-12
One approved MATH elective chosen in consultation with the academic adviser.

Other required courses
CS 410, Introduction to Scientific Programming
EDUC 500, Exploring Teaching
EDUC 700, Educational Structure and Change
EDUC 701, Human Development and Learning: Educational Psychology
EDUC 705, Alternative Perspectives on the Nature of Education

Note: EDUC 751 is a requirement for certification that may be taken as an undergraduate.

Minoring in Mathematics

The Department of Mathematics and Statistics offers three minor programs: mathematics, applied mathematics, and statistics. These programs, which are open to all students enrolled at the University, require a minimum of five MATH courses as detailed below. Students whose major program requires more than two courses required by the minor program must substitute additional courses from the list of optional courses to meet the five-course minimum.

Mathematics Minor
Required (3): MATH 528*, MATH 531 (and MATH 761 (or 767)
Options (2): Two courses chosen from: MATH 527*, 656, 657, 658, 761, 762, 764, 767, 776, 783, 784, 788

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Applied Mathematics Minor
Required (4): MATH 527*, 528*, 645* (or 545), and 753
Options (1): One course chosen from: MATH 539, 644, 646, 647, 745, 746, 747, or 754

*These requirements can be satisfied by MATH 525-526, Linearity I-II.

Statistics Minor
Required (2): MATH 539 (or 644) and MATH 645 (or 545)
Options (3): Three courses chosen from: MATH 737, 739, 740, 741, 742, 744, 755, 756

Mechanical Engineering (ME)

www.unh.edu/mechanical-engineering/

(For course descriptions, see page 219.)

Chairperson: Todd S. Gross

Professor: Kenneth C. Baldwin, Barbaros Celikkol, Barry K. Fussell, Todd S. Gross, Robert Jerard, Joseph C. Klewicki, James E. Krzanowski, M. Robinson Swift

Affiliate Professor: Donald M. Esterling

Associate Professor: Gregory P. Chini, Brad Lee Kinsey, John Philip McHugh, May-Win L. Thein, Igor I. Tsukrov

Affiliate Associate Professor: Vladimir Riabov

Assistant Professor: Diane Foster, Christopher M. White, Martin M. Wosnik

Affiliate Assistant Professor: Gary Lapham, Timothy Upton

The Mechanical Engineering Program at UNH is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

Mission

In support of the University and college missions, the Department of Mechanical Engineering is dedicated to educating the highest quality engineering professionals and leaders. Graduates will be prepared to creatively solve engineering problems through the use of analysis, computation, and experimentation. Students completing the program should be well-informed citizens who have the ability to grow intellectually and are able to solve new, challenging problems with self-confidence. It is the department's intent to maintain a general and flexible curriculum that prepares students for both industrial practice and graduate education.

Educational Objectives

The goal of the UNH mechanical engineering program is to produce graduates who are good professionals and good citizens who 1) skillfully apply the fundamental principles of mathematics, science, and engineering; 2) solve engineering problems by integrating strong design, analysis, and experimental abilities with excellent communication skills; 3) successfully contribute to their respective corporate, government, or academic organizations; 4) demonstrate continuous growth by assuming positions of leadership in their profession, or by becoming successful entrepreneurs; by successfully completing advanced degrees and professional education; 5) are broadly educated citizens of society with an understanding of the impact of engineering solutions in a global/societal context; and 6) demonstrate a high level of personal and social integrity through their ethical behavior and service to their peers, employers, communities, the nation, and the world.

Mechanical engineering is a challenging profession encompassing research, design, development, and production of aerospace vehicles, underwater vessels, instrumentation and control systems, nuclear and conventional power plants, and consumer and industrial products in general. The profession also makes contributions through more fundamental studies of material behavior, the mechanics of solids and fluids, and energy transformation. Additional information can be found at the mechanical engineering Web site, www.unh.edu/mechanical-engineering.

The Program

The program begins with courses in physics, mathematics, chemistry, and computer-aided design. The department has a four-semester mechanics thread, a four-semester thread in the thermal/fluid sciences, and a three-semester thread in systems and controls. Modern experimental methods are taught in a two-semester course starting in the junior year. The two-semester senior design project requires students to utilize the skills they have learned in their courses and to learn how to function in an engineering team. The five technical electives offered in the program give the students the opportunity to focus on advanced technical areas of their choice.

With their advisers' assistance, students should plan a program, based on the following distribution of courses, that totals not less than 128 credits. The outline that follows is typical only in format. Within the constraints of satisfying all the requirements and having all the necessary prerequisites, schedules may vary because of scheduling needs or student preference. Some mechanical engineering elective courses may not be offered every year.

The curriculum has 11 elective courses. These should be selected in consultation with a departmental adviser to lead to a balanced program that addresses chosen areas of interest. Five of the elective courses are selected from groups four through eight of the University's general education requirements, with the Group 7 general education course being either ECON 402 or EREC 411. One of the elective courses must be selected from the biological science listing of Group 3 of the general education requirements.

Five technical elective courses of at least three credits each are required. These may be selected from 600-700 level courses in the College of Engineering and Physical Sciences, except for one course that may be selected from one of the following 400-500 level courses: ME 442, ME 542, ENE 520, ESCI 501, and ECE 543. Two technical electives can be used for studying a focused area such as a foreign language, professional program, or minor, with department approval.

Some programs may require additional elective courses to reach the minimum of 128 credits required for graduation. Other programs may exceed 128 credits to include all the required courses.

Predictor courses: To enter the junior-year in the mechanical engineering major, students must achieve a minimum grade-point average of 2.0 with no grade below C- in the following courses: Physics 407, Math 426, ME 525, ME 526, and ME 503.

In order to graduate in the mechanical engineering major, students must have at least a 2.0 grade-point average in all engineering and science courses, including required technical electives normally taken as department requirements after the start of the junior year.

Freshman Year	**Fall**	**Spring**
MATH 425, Calculus I	4	-
*CHEM 405, General Chemistry	4	-
ME 441, Engineering Graphics	4	-
General Education Elective	4	-
MATH 426, Calculus II	-	4
PHYS 407, General Physics I	-	4
General Education Elective	-	4
English 401	-	4
Total	**16**	**16**

*CHEM 403 and CHEM 404, General Chemistry, may be substituted for CHEM 405.

Sophomore Year	**Fall**	**Spring**
**MATH 527, Differential Equations	-	4
**MATH 528, Multidimensional Calculus	4	-
ME 525, Mechanics I	3	-
ME 503, Thermodynamics	-	3
ME 561, Introduction to Materials Science	-	4
PHYS 408, General Physics II	4	-
Technical Elective	3-4	-
ME 526, Mechanics II	-	3
General Education Elective	4	-
Total	**18-19**	**14**

**MATH 525 and 526, Linearity, may be substituted for MATH 527 and 528, and a technical elective course.

Junior Year	**Fall**	**Spring**
General Education Elective	4	-
ME 608, Fluid Dynamics	3	-
ME 627, Mechanics III	3	-
ME 643, Elements of Design	-	3
ECE 537, Introduction to Electrical Engineering	4	-
ME 603, Heat Transfer	-	3
ME 646, Experimental Measurement & Data Analysis	-	4
ME 670, Systems Modeling, Simulation, & Control	-	4
CS 410, Intro to Scientific Programming	4	-
Total	**18**	**14**

Senior Year	Fall	Spring
ME 705, Thermal System Analysis and Design	4	-
***ME 755, Senior Design Project I	2	-
ME 747, Experimental Measurement & Modeling	4	-
General Education Elective	4	-
Technical Elective	3-4	-
ME 756, Senior Design Project II	-	2
Technical Elective	-	3-4
Technical Elective	-	3-4
General Education Elective	-	4
Technical Elective		3-4
Total	**17-18**	**15-18**

***TECH 797, Undergraduate Ocean Research Project, may be substituted for ME 755 and ME 756

Mechanical Engineering Minor

The minor, administered by the Department of Mechanical Engineering, is open to all students of the University and offers a broad introduction to mechanical engineering.

Students must complete a minimum of six courses as follows: ME 441, ME 525, ME 526, ME 627, ME 503, and ME 608. Electrical and Computer Engineering majors should take the following courses: ME 441, ME 523, ME 526, ME 503, ME 608, and ME 561.

Interseted students should contact the mechanical engineering chair, Todd Gross, (603) 862-2445.

Materials Science Minor

The minor, administered by the Department of Mechanical Engineering, is open to all students of the University and offers a broad introduction to materials science.

Students must complete at least 18 credits and a minimum of five courses as follows: ME 561 (required); ME 760 (required); and ME 730 (required); and two additional courses from the following: 731, 744, 761, 762, 763, and 795 (materials).

By mid-semester of their junior year, interested students should consult the minor supervisor, James E. Krzanowski, Department of Mechanical Engineering (603) 862-2315.

Physics (PHYS)

www.physics.unh.edu/

(For course descriptions, see page 237.)

Chairperson: Eberhard Möbius

Professor: L. Christian Balling, Amitava Bhattacharjee, John R. Calarco, Olof E. Echt, James M.E. Harper, F. William Hersman, Martin A. Lee, Eberhard Möbius, James M. Ryan, Roy B. Torbert

Research Professor: Terry Forbes, Philip A. Isenberg, Nelson Maynard, R. Bruce McKibben, Charles W. Smith III

Associate Professor: Per Berglund, Benjamin D. Chandran, James Connell, Maurik Holtrop, Lynn M. Kistler, Mark L. McConnell, Dawn C. Meredith, Karsten Pohl, Joachim Raeder

Research Associate Professor: Charles J. Farrugia, Antoinette B. Galvin, Harold A. Kucharek, Mark R. Lessard, Yuri E. Litvinenko, Clifford Lopate, Bernard J. Vasquez

Assistant Professor: Silas Robert Beane III, Kai Germaschewski, Karl Silfer, Jian-Ming Tang

Research Assistant Professor: Li-Jen Chen

Physics is concerned with the properties of matter and the laws that describe its behavior. It is an exact science based on precise measurement, and its objective is the kind of understanding that leads to the formulation of mathematical relationships between measured quantities. As a fundamental science, its discoveries and laws are basic to understanding in nearly all areas of science and technology. Advances in such diverse fields as medical instrumentation, solid state electronics, and space research have relied heavily on the application of basic physical laws and principles.

Students interested in the study of physics at the University of New Hampshire will find a strong interaction between research and academic programs. Undergraduates have participated in research studies ranging from nuclear scattering experiments at major particle accelerators to astrophysical studies of the solar system using space probes. These experiences have proven beneficial to engineering and physics students alike. The department is located in DeMeritt Hall (completed in 2008) and Morse Hall. Both buildings are equipped with state-of-the art research facilities and laboratories. DeMeritt Hall also houses the physics library, classrooms, and a number of open and comfortable meeting areas, which provide an inviting atmosphere for study, interaction, and collaboration.

The suggested programs that follow are indicative of the flexibility available to students, whether they are preparing for graduate work in physics or astronomy, industrial opportunities, governmental research, secondary-level teaching, or a general education that might utilize the fundamental knowledge of physics.

Several undergraduate degree programs are offered through the department of physics. The B.S. degree is designed for students who wish to work as professional physicists or engineers; the interdisciplinary options in chemical physics, materials science, and astronomy allow students to combine physics with other disciplines. The B.A. degree is designed for students who want a strong background in physics but also want a broad liberal arts education. A minor in physics allows a student to combine an interest in physics with another major.

Physics-related degrees are also offered in other departments. For those students with strong interests in both math and physics, the Department of Mathematics offers a B.S. interdisciplinary option in physics. For those interested in a career as a middle- or high-school educator in both physics and chemistry, the Department of Chemistry offers a B.A. in chemistry and physics teaching.

Interested students are encouraged to contact the department for further information. More detailed information is also on the physics department Web page at www.physics.unh.edu.

Minor in Physics

The minor in physics consists of five courses in physics. All students must take PHYS 407, 408, and 505, including labs. Two other physics courses at the 500 level or above must be chosen in consultation with the student's physics minor adviser.

Bachelor of Arts, Chemistry and Physics Teaching

(For program description, see page 61.)

Physics Major, Bachelor of Arts

This degree provides an opportunity for a broad and liberal arts education, which in some cases may be sufficient for graduate work. A judicious choice of electives may also prepare students for interdisciplinary programs that require proficiency in a restricted area of physics.

Requirements

1. Satisfy general education and writing requirements.

2. Satisfy bachelor of arts degree requirements.

3. PHYS 400, 407-408, 505, 506, 508, 605, 615, 616, 701, 703, 705. Note that MATH 425, 426, and MATH 525, 526 or MATH 527, 528 are prerequisites for some of the courses.

In the following table, "Electives" include general education courses, writing intensive courses, language courses required for the B.A., and free choice electives.

Suggested Curriculum for B.A. in Physics

Freshman Year	**Fall**	**Spring**
PHYS, 400, Freshman Seminar	1	-
PHYS, 407-408, General Physics I and II	4	4
MATH, 425, 426, Calculus I and II (Group 2)	4	4
ENGL 401, First-Year Writing	-	4
Elective	8	4
Total	**17**	**16**
Sophomore Year	**Fall**	**Spring**
PHYS 505-506, General Physics III and Lab	4	-
PHYS 615, Classical Mechanics and Mathematical Physics I	-	4
MATH 525, Linearity I *or* MATH 527, Differential Equations	6 or 4	-
MATH 526, Linearity II *or* MATH 528, Multidimensional Calculus	-	6 or 4
Elective	8	8
Total	**16 or 18**	**16 or 18**
Junior Year	**Fall**	**Spring**
PHYS 605, Experimental Physics I	5	-
PHYS 508, Thermodynamics and Statistical Mechanics	-	4
PHYS 616, Classical Mechanics and Mathematical Physics II	4	-
PHYS 701, Introduction to Quantum Mechanics I	-	4
Electives	8	8
Total	**17**	**16**
Senior Year	**Fall**	**Spring**
PHYS 705, Experimental Physics II	-	4
PHYS 703, Electricity and Magnetism I	-	4
Elective	16	8
Total	**16**	**16**

Bachelor of Science in Physics

The bachelor of science degree in physics prepares students for professional work as physicists. The required courses are those typically necessary for admission to graduate study in physics or astronomy. The interdisciplinary options require fewer physics courses combined with a concentration in another area (chemistry or materials science). The astronomy option emphasizes courses that help prepare a student for advanced studies in astronomy.

Requirements

1. Satisfy general education and writing requirements.

2. Satisfy bachelor of science university requirements.

3. Minimum physics requirements: 400, 407-408, 505, 506, 508, 605, 615-616, 701, 702, 703, 704, 705; two physics electives selected from the 700-level physics courses.

4. Chemistry: 403-404 or 405

5. Math: 425-426, and 525-526 or 527-528

6. Computer Science: CS 410

7. By the end of the spring semester of the sophomore year, a student must have a minimum grade of C in each 400- or 500-level course specifically required for the B.S. degree and an overall grade-point average of at least 2.33 in these courses in order to continue in the B.S. program.

Physics electives

In the following table, "Electives" include general education courses, writing intensive courses, physics electives, and free choice electives. Note that physics electives can only be taken in the junior or senior year because of prerequisites, and are in general offered every other year.

Suggested Curriculum for B.S. in Physics

Freshman Year	**Fall**	**Spring**
PHYS 400, Freshman Seminar	1	-
PHYS 407-408, General Physics I and II	4	4
MATH 425, 426, Calculus I and II (Group 2)	4	4
CHEM 403-404, General Chemistry (Group 3)	4	4
ENGL 401, Freshman English	-	4
Elective	4	-
Total	**17**	**16**
Sophomore Year	**Fall**	**Spring**
PHYS 505-506, General Physics III and Lab	4	-
PHYS 508, Thermodynamics and Statistical Mechanics	-	4
PHYS 615, Classical Mechanics and Mathematical Physics I	-	4
MATH 525, Linearity I or MATH 527, Differential Equations	6 or 4	-
MATH 526, Linearity II or MATH 528, Multidimensional Calculus	-	6 or 4
CS 410, Introduction to Scientific Programming	4	-
Elective	4	4
Total	**16 or 18**	**16 or 18**
Junior Year	**Fall**	**Spring**
PHYS 605, Experimental Physics I	5	-
PHYS 616, Classical Mechanics and Mathematical Physics II	4	-
PHYS 701, Introduction to Quantum Mechanics I	-	4
PHYS 703, Electricity and Magnetism I	-	4
Electives	8	8
Total	**17**	**16**
Senior Year	**Fall**	**Spring**
PHYS 702, Quantum Mechanics II	4	-
PHYS 704, Electricity and Magnetism II	4	-
PHYS 705, Experimental Physics II	-	4
Elective	8	12
Total	**16**	**16**

Chemical Physics Option, Bachelor of Science in Physics

1. Satisfy general education and writing requirements.

2. Satisfy bachelor of science University requirements.

3. Physics requirements: PHYS 400, 407-408, 505-506, 508, 605, 615, 616, 701, 702, 703, 705.

4. Chemistry: CHEM 403, 404, 683-686, 762, 763, 776

5. Mathematics: MATH 425-426, 525-526 or 527-528

6. Computer Science: CS 410

7. Electives in Option: Two courses selected from CHEM 547/9, MATH 646, PHYS 718, PHYS 795

8. By the end of the spring semester of the sophomore year, a student must have a minimum grade of C in each 400- or 500-level course specifically required for the B.S. degree and an overall grade-point average of at least 2.33 in these courses in order to continue in the B.S. program.

Materials Science Option, Bachelor of Science in Physics

1. Satisfy general education and writing requirements.

2. Satisfy bachelor of science University requirements.

3. Physics requirements: PHYS 400, 407-408, 505-506, 508, 605, 615-616, 701, 703, 705, 795 (4 credit hours), 799 (4 credit hours).

4. Mechanical Engineering: 561, 730, 760

5. Math: 425-426, 525-526, or 527-528

6. Computer Science: CS 410

7. Electives in Option: Three courses selected from MATH 646, ME 731, 761, 762, 763, 795, PHYS 718

8. Chemistry: 403-404 or 405

9. By the end of the spring semester of the sophomore year, a student must have a minimum grade of C in each 400- or 500-level course specifically required for the B.S. degree and an overall grade-point average of at least 2.33 in these courses in order to continue in the B.S. program.

Astronomy Option, Bachelor of Science in Physics

1. Satisfy general education and writing requirements.

2. Satisfy bachelor of science University requirements.

3. Physics requirements: PHYS 400, 406, 407-408, 505, 506, 508, 605, 615-616, 701, 702, 703, 704, 705, 710, 795 (4 credit hours), 799 (4 credit hours).

4. Chemistry: CHEM 403-404 or CHEM 405

5. Math: MATH 425-426 and 525-526 or 527-528

6. Computer Science: CS 410

7. Elective in option: Choose one course from PHYS 708, PHYS 712, PHYS 720, PHYS 764, PHYS 791

8. By the end of the spring semester of the sophomore year, a student must have a minimum grade of C in each 400- or 500-level course specifically required for the B.S. degree and an overall grade-point average of at least 2.33 in these courses in order to continue in the B.S. program.