
AUSTRALIA
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College of Engineering

The College of Engineering was established as a distinct unit of the University in 1897, although a program in civil engineering was offered in 1873. It is now organized into five departments, including aerospace and mechanical engineering, chemical and biomolecular engineering, civil engineering and geological sciences, computer science and engineering, and electrical engineering.

Since its inception, the College of Engineering regards the primary purpose of all higher education as the development of the intellect, discriminatory power, and judgment in all students to enable them to arrive at sound decisions in their personal lives and in the professional lives they will pursue after graduation. The programs of studies offered in the various departments of the college are, therefore, constructed to give the student a good knowledge of the basic sciences and of engineering principles, and to prepare him or her for the manifold duties of an educated professional and for the cultural life of an educated person. Classroom instruction is amplified by laboratory work and design experiences that give the student some insight into the application of principles to practical problems. Detailed excursions about the College of Engineering and its many programs can be found on the World Wide Web at www.nd.edu/~engineer.

Mission Statement. To nurture the intellectual growth of our students and to serve humanity through the creation, application, and dissemination of knowledge relevant to technology.

Accreditation and Academic Association. The College of Engineering is a member of the American Society for Engineering Education, and all engineering curricula are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Registration of Engineers. Registration of engineers is required for many fields of practice. While young engineers need not acquire registration immediately upon graduation, they benefit by applying early for the required state examination. Graduating from accredited programs such as those offered by Notre Dame facilitates registration as a professional engineer.

Registration of Geoscientists. Registration is required for geoscientists to practice in many states. The degree in environmental geosciences (available through the Department of Civil Engineering and Geological Sciences) provides the necessary academic background for graduates to succesfully complete registration as a professional geoscientist.

Programs and Degrees

The College of Engineering offers curricula leading to the degrees listed below:

B.S. in aerospace engineering
B.S. in chemical engineering
B.S. in civil engineering
B.S. in computer engineering
B.S. in computer science
B.S. in electrical engineering
B.S. in environmental geosciences
B.S. in mechanical engineering

To complete all the degree requirements, the student must take and pass all of the courses specified in the *Bulletin* for the given degree and must earn the total minimum number of course credit hours specified for the degree.

To obtain two undergraduate degrees from the College of Engineering, a student must successfully carry out an approved program of courses totaling at least 164 credit hours. These must include all of the courses specified in the *Bulletin* for each degree.

The master of science and doctor of philosophy degrees are offered in the fields of engineering listed above. The Department of Civil Engineering and Geological Sciences has programs leading to the degrees of master of science in environmental engineering, master of science in bioengineering, and master of science in geological sciences.

The Department of Computer Science and Engineering offers one master's degree, the master of science in computer science and engineering, and the doctor of philosophy.

The details of the programs and the engineering courses offered at the graduate level are in the *Graduate School Bulletin of Information.*

Engineering Common Core. All engineering curricula consist of each of the following:

Arts and Letters: 24 credit hours. Composition (one course), University Seminar* (one course), history (one course), social science (one course), fine arts or literature (one course), philosophy (two courses) and theology (two courses).

**The University Seminar may be selected from an appropriate history, social science, fine arts or literature course or the first course in theology or philosophy.*

Basic Science Core: 36 credit hours. MATH 125. Calculus I, MATH 126. Calculus II, MATH 225. Calculus III, MATH 228. Introduction to Linear Algebra and Differential Equations, CHEM 121. General Chemistry: Fundamental Principles, CHEM 122. General Chemistry: Biological Processes, PHYS 131. General Physics I, PHYS 132. General Physics II, EG 111, 112: Introduction to Engineering Systems I and II

Program of Studies. The course of studies for first-year students intending to major in any program of the College of Engineering is completely uniform so that the student who is undecided as to a specialty may postpone the final choice until the spring semester of the first year. Included in the college are six engineering programs (aerospace, chemical, civil, computer, electrical, and mechanical) and two non-engineering programs (computer science and environmental geosciences). First-year students intending to pursue any of these programs should consult this *Bulletin* for the **Program of Studies.**

An entering student simply makes a "declaration of intent" of the undergraduate college which he or she proposes to enter as a sophomore and is not enrolled in a particular college as a first-year student.

First Year of Studies. The beginning college student who has been accepted as a first-year student enters the Notre Dame First Year of Studies. Here the student will have one academic year of basic collegiate studies before entering a given department and college. Before entrance as a first-year student, the student will have made a tentative declaration of intention to major in a given college. This declared intention serves as a guideline for the student and the advisors and counselors. In the spring of the first year of studies, with three-fourths of an academic year of actual experience at Notre Dame and with the benefit of counsel and advice received from the appropriate officials and University faculty, the first-year student will make a decision as to the department and college in which the student chooses to major. If the student is scholastically sound for the given choice, approval will be given.

A first-year student intending to major in any of the College of Engineering programs should take the following courses in the first year:

First Semester

Composition or University Seminar+	3
MATH 125. Calculus I	4
CHEM 121. General Chemistry: Fundamental Principles	4
Arts and Letters course*	3
EG 111. Introduction to Engineering Systems I#	3
Physical Education	—
	17

Second Semester

University Seminar+ or Composition	3
MATH 126. Calculus II	4
CHEM 122. General Chemistry: Biological Processes	3
PHYS 131. General Physics I	4
EG 112. Introduction to Engineering Systems II#	3
Physical Education	—
	17

+ *The University Seminar may be selected from an appropriate history, social science, fine arts or literature course, or the first course in theology or philosophy.*

**See Humanities in the Curriculum on this page.*

While EG 111–112 is acceptable for the environmental geosciences degree, it is not required and the sequence ENVG 131–112 may be substituted.

General Requirements. The University of Notre Dame reserves the right to change at any time regulations included in its *Bulletins* with respect to admission to the University, continuance therein and graduation therefrom. Every effort is made to give advance information of such changes.

All first-year students are required to take physical education three periods a week the first year. Relaxation of this rule for ROTC students is noted below.

The number of credit hours, exclusive of ROTC, usually carried by the undergraduate student in the College of Engineering varies from 14 to 18 in accordance with the program of courses listed elsewhere and may not exceed 19 hours. The permissible maximum may be lowered or increased at the discretion of the dean.

An upperclass student who desires to transfer from engineering to another college of the University or from one department of the college to another department must obtain the specified approvals.

International Study Opportunities. The University strongly supports study abroad and has encouraged the programs in the College of Engineering to participate. At present, there are opportunities in six locations: Dublin, Ireland; London, England; Perth, Australia; Monterrey, Mexico; Karlsruhe, Germany; and Cairo, Egypt. The programs in Mexico and Germany require the student to be fluent in Spanish and German, respectively. In each location, students are required to take at least two technical courses so as to be able to graduate in four years with their classmates. Students may go to the London Engineering Program either during the summer after their sophomore or junior year or during the first semester of the junior year. The program in Karlsruhe must be taken in the second semester of the junior year, while those in Monterrey and Cairo are best taken in the second semester of the junior year. Not all locations are appropriate for every program in the college. Students should contact an advisor in their department to work out any details.

ROTC Programs. In the first year of studies, all ROTC students omit physical education, in accordance with the academic regulations.

ROTC students are permitted a maximum of six credits of upper-level air, military or naval science as substitutes for specified degree requirements determined by the department. Three of these credits may be substituted for either a history or social science requirement. All air, military or naval science credits not so substituted are not credited toward degree requirements in programs in the College of Engineering.

Humanities in the Curriculum. The student enrolled in the College of Engineering is required to satisfy all University degree requirements, which include composition (three credits), University Seminar* (three credits), history (three credits), social science (three credits), fine arts or literature (three credits), philosophy (six credits) and theology (six credits).

For specific information on course offerings to satisfy these requirements, the student is expected to confer with a departmental advisor. A list of such courses scheduled each semester will be made available by the student's advisor. ROTC students may be permitted to substitute three credits of upper-level air, military or naval science for either the history or social science requirement.

** The University Seminar may be selected from an appropriate history, social science, fine arts or literature course, or the first course in theology or philosophy and will satisfy the respective requirement.*

Engineering Business Practice. The college recognizes the importance of providing its graduates with opportunities to learn how engineers function in the world of business, and several departments do provide courses that are specifically tailored to provide skills, insight, and experience related to business practice by engineers.

A new multi-course sequence has been developed in the college that will provide additional opportunities in this area. The sequence can be taken by students in all departments of the college and is designed to increase the effectiveness of engineering graduates by developing an understanding of the dynamics of business operations. These courses include issues related to ethics, leadership, and business practices such as marketing, management, finance, and human resources, and to examine the professional and leadership characteristics of modern industrial leaders. In the second course, students are expected to develop a business plan and execute it using a well-known computer simulation program.

Combination Five-Year Programs with the College of Arts and Letters. The engineering executive in modern industry should have a broad background in cultural, social, and technical subjects. Some allowance is made for this in the prescribed four-year curricula, but in view of the extent of the technical field that must be presented, coverage of the cultural field is necessarily limited.

To realize the desired objective more fully, the College of Engineering, in cooperation with the College of Arts and Letters of the University, instituted in 1952, a five-year program that combines the basic stem of the liberal arts program with the technical requirements of the various engineering programs. The student completing this combination program will be awarded two degrees: the degree of bachelor of arts and the degree of bachelor of science in the professional course pursued.

Students pursuing this program must have strong scholastic ability and be acceptable to both the dean of the College of Arts and Letters and the dean of the College of Engineering. Choice of the program should be indicated by the end of the first year, but choice of a particular field of Arts and Letters may be deferred until the end of the second year.

The general sequence of courses in the five-year engineering-liberal arts program is found under "Dual Degree Programs," later in this section of the *Bulletin.*

Combination Five-Year Program with the Mendoza College of Business. To address the needs of engineering students who wish to integrate management and engineering, the College of Engineering and the Mendoza College of Business have established a competitive cooperative program in which a student may earn the bachelor of science from the College of Engineering and the master of business administration in five years plus some summer sessions.

The program is structured so that a student who has completed the first three years of the bachelor's degree program, if accepted, completes the master of business administration and the bachelor of science in a summer session and two subsequent academic years.

Students who wish to pursue this program should have a superior scholastic record in their undergraduate program and must make application to and be accepted by the M.B.A. program.

The general sequence of courses in the five-year engineering-M.B.A. program may be found under "Dual Degree Programs," later in this section of the *Bulletin.*

Combination Five-Year Programs with Other Schools. The highly desirable objective to infuse more liberal arts work into the education of engineering students has been met in another way.

The University of Notre Dame has entered into agreements with Bethel College, Mishawaka, Ind.; Saint Mary's College, Notre Dame, Ind.; St. Anselm College, Manchester, N.H.; College of St. Thomas, St. Paul, Minn.; Carroll College, Helena, Mont.; Stonehill College, North Easton, Mass.; and the University of St. Thomas, Houston, Tex., whereby the liberal arts part of combination five-year programs is given by these respective colleges and the engineering part by Notre Dame. In these cooperative programs, the student spends three years at a college of first choice and two years at Notre Dame. After completion of the program, the student receives a bachelor of arts degree from the first college and a bachelor of science degree in a College of Engineering program from Notre Dame.

The sequence of courses is essentially the same as in the Notre Dame engineering-liberal arts program; however, no attempt has been made to set up a rigid pattern, and each participating institution has complete freedom concerning the choice and arrangement of courses, provided that the coverage in the areas of mathematics, physics, chemistry, computing, introductory engineering, theology, philosophy, history, social science, and literature or fine arts is appropriate. It is expected that the equivalent of the first two years of the College of Engineering program being applied for has been completed before transfer.

Details of these programs may be obtained by writing to the institutions concerned or to the dean of the College of Engineering.

Graduate Programs in Engineering.* The Graduate School of the University of Notre Dame is composed of four divisions: humanities, social science, science, and engineering. The division of engineering of the Graduate School was organized in 1946 with power to grant advanced degrees in the departments of aerospace and mechanical engineering, chemical and biomolecular engineering, civil engineering and geological sciences, computer science and engineering, and electrical engineering. The general conduct of graduate work is under the jurisdiction of the Graduate Council of the University, the members of which serve as specified in the *Academic Articles.* Director of the program in the engineering division is the dean of the College of Engineering.

** Reference should be made to the Graduate School Bulletin of Information for details of these programs and to the World Wide Web at www.nd.edu/~engineer/prospects/prospects.htm.*

The Scope of the Graduate Program. Extensive graduate work in engineering takes place in the College of Engineering and encompasses all of its programs. The greater emphasis of today on research in industry and in governmental institutions has increased the demand for engineers with graduate degrees and made it desirable to include graduate work in the engineering curriculum. Both undergraduate and graduate students benefit from the advanced technological ideas being studied and developed.

Facilities for Graduate Work. All departments of the college have special laboratories, equipment and study rooms for graduate students. General facilities available include a high-performance computing facility, the University library and its special collections, the research libraries in science and engineering, and the various research laboratories. The nearness of Chicago makes possible a certain amount of cooperation with the scientific institutions and special libraries of that city, and the concentration of industrial plants in nearby South Bend and the surrounding area provides excellent opportunity for study in the field and for cooperative research with industry.

College Awards and Prizes

COLLEGE OF ENGINEERING AWARD

The Rev. Thomas A. Steiner Prize. From a fund established in 1948 by former students of Rev. Thomas A. Steiner, C.S.C., former dean of the College of Engineering, a cash award is made to seniors in any department of the college who have been selected for their all-around excellence as students.

DEPARTMENTAL AWARDS

AEROSPACE AND MECHANICAL ENGINEERING

Patrick J. Deviny Award. Presented each year to a junior aerospace student who has displayed the most diligence and persistence in the pursuit of undergraduate studies in aerospace engineering.

Vincent P. Goddard Design Award. Presented each year to a senior in aerospace engineering for the best design in the senior aerospace design course.

Sigma Gamma Tau Honor Award. Presented to the outstanding graduate of the Aerospace Engineering Program.

The Zahm Prize for Aeronautical Engineering was founded in 1946 by Dr. Albert J. Zahm, distinguished pioneer in aeronautics and at one time professor of physics at the University of Notre Dame. The award is made by the program in Aerospace Engineering to the senior student of the program who, in the estimation of the faculty of the program, has achieved the most distinguished record in professional subjects.

Joannes Westerink

Associate Professor of Civil Engineering and Geological Sciences

2004 Recipient of the College of Engineering Outstanding Teacher Award

American Society of Mechanical Engineers Certificate of Award. Presented each year to the outstanding student member of the Notre Dame Student Section of ASME.

Jerome L. Novotny Design Award. Presented each year to a senior in mechanical engineering for the best design in the senior heat transfer course.

CHEMICAL AND BIOMOLECULAR ENGINEERING

AIChE Scholarship Award. A certificate and a copy of Perry's *Chemical Engineers' Handbook* awarded to the junior chemical and biomolecular engineering student who has the highest scholastic average during the first two years of study.

American Institute of Chemists Award. A certificate awarded each year to an outstanding senior in the Department of Chemical and Biomolecular Engineering.

Chemical Engineering Alumni Award. A certificate and a cash award to one or more seniors having an outstanding combination of scholarship and extracurricular activities.

Chemical Engineering Faculty Award. A certificate and a cash award to the senior having the highest scholastic average after seven semesters of study.

Chemical Engineering Research Award. A certificate and cash award to one or more undergraduate students considered to have performed outstanding undergraduate research.

CIVIL ENGINEERING AND GEOLOGICAL SCIENCES

The American Society of Civil Engineers. The Indiana Section presents each year an award to the two senior students most active in the Student Chapter of ASCE.

Leroy D. Graves Academic Improvement Award. Presented to a senior civil engineering student for significant development in academic performance.

The Sydney Kelsey Outstanding Scholar Award. Presented to a senior civil engineering student for excellence and creativity in academics.

The Kenneth R. Lauer Award. Presented to a senior civil engineering student for leadership, integrity, and service to fellow students and community as determined by that student's classmates.

James A. McCarthy Scholarship in Civil Engineering. Presented to a junior civil engineering student for outstanding academic and professional excellence.

The Walter L. Shilts Award for Undergraduate Achievement. Presented to a senior civil engineering student who has best fulfilled his or her potential as a student through hard work and dedication to obtaining the best possible education.

The Rev. Alexander Kirsch, C.S.C., Award. To the senior receiving a degree in geological sciences who has evidenced high qualities of personal character, scholarship, and leadership.

Dr. Raymond C. Gutschick Award. To the graduating senior who has demonstrated the most promise in geological research as evidenced by a successful research project.

COMPUTER SCIENCE AND ENGINEERING

Outstanding Computer Engineering Award. To the graduating senior in computer engineering who has evidenced high qualities of personal character, scholarship, and leadership.

Outstanding Computer Science Award. To the graduating senior in computer science who has evidenced high qualities of personal character, scholarship, and leadership.

ELECTRICAL ENGINEERING

The Basil R. Myers Award. For achievement in electrical engineering, recalling circuit theory, the English language, and St. George Day at Notre Dame.

The James L. Massey Award. For achievement in electrical engineering, recalling communication theory, undergraduate teaching, and the Binary Examination.

The Arthur J. Quigley Award. For achievement in electrical engineering, recalling electronics, service to our neighbor, and the little man in the circuit.

The Laurence F. Stauder Award. For achievement in electrical engineering, recalling electrical power, the IEEE Student Branch, and the Notre Dame Alumni.

The IEC William L. Everitt Award. For achievement in electrical engineering, computer engineering, or computer science, with an interest in the area of communications.

Student Organizations and Activities

THE NOTRE DAME TECHNICAL REVIEW

Since 1949, the students of the College of Engineering have been publishing the *Notre Dame Technical Review* at least three times each school year. It provides the opportunity for creative writing and for the management of a technical periodical. All the students support this activity and encourage wide participation by purchasing an annual subscription at a nominal rate.

HONOR SOCIETIES

TAU BETA PI

The Indiana Gamma Chapter of Tau Beta Pi was installed at Notre Dame in 1960 to foster a spirit of liberal culture in the engineering college and to recognize those who have conferred honor upon Notre Dame by distinguished scholarship and exemplary character as undergraduates in engineering or by their attainment as alumni in the field of engineering. Seniors and juniors in the top fifth and top eighth of their respective classes are eligible for election under rigid standards of scholarship, character, leadership, and service.

ETA KAPPA NU

In 1962, the Delta Sigma Chapter of Eta Kappa Nu, the national honor society for electrical engineers, was installed at Notre Dame. Juniors, seniors, and alumni eligible for membership because of scholastic attainment, leadership, and quality of character may be identified with this association and may avail themselves of the privileges it affords.

PI TAU SIGMA

In 1963, the Sigma Beta Chapter of Pi Tau Sigma, the national honor society for mechanical engineers, was installed at Notre Dame. Juniors, seniors, and alumni qualify for membership by scholastic attainment, leadership, quality of character, and a demonstration of probable future success in engineering.

CHI EPSILON

The Notre Dame Chapter of Chi Epsilon, the national honor society for civil engineers, was installed at Notre Dame in 1966. The purpose of Chi Epsilon is to give recognition to those civil engineering students, faculty, and alumni who have displayed superior qualities in scholarship, character, practicality, and sociability during their professional careers.

SIGMA GAMMA TAU

The Notre Dame Chapter of the national honor society for Aerospace Engineering was installed in 1981. This organization recognizes and honors those individuals in the field of aeronautics and astronautics who have distinguished themselves through scholarship, integrity, service, and outstanding achievement. Senior students who rank in the top third of their aerospace engineering class are eligible for admission.

PROFESSIONAL SOCIETIES

The several departments of the college actively support student chapters of their respective professional societies; these are:

The American Institute of Chemical Engineers
The American Society of Civil Engineers
The American Society of Mechanical Engineers
The American Institute of Aeronautics and Astronautics
The Institute of Electrical and Electronic Engineers
The Society of Women Engineers
The Society of Black Engineers
The Society of Hispanic Engineers

The Joint Engineering Council, a student organization, with representation from the student chapters of the professional and honor societies, serves to coordinate the activities of those chapters and encourages the pursuit of a professional attitude in the student body of the College of Engineering. The JEC serves to sponsor all those activities which are of general interest to the engineering student body.

Programs of Study

Aerospace and Mechanical Engineering

Chair:
Stephen M. Batill
H. Clifford and Evelyn A. Brosey Professor of Mechanical Engineering:
Frank P. Incropera
Roth-Gibson Professor of Aerospace Engineering:
Thomas J. Mueller
Viola D. Hank Professor of Mechanical Engineering:
Hafiz M. Atassi
Viola D. Hank Professor of Mechanical Engineering:
Lisa A. Pruitt
Clark Professor:
Thomas C. Corke
Professors:
Stephen M. Batill; Raymond M. Brach (emeritus); Roy D. Crowninshield(adjunct), Patrick F. Dunn; Nai-Chien Huang (emeritus); Edward W. Jerger (emeritus); Eric J. Jumper; Francis M. Kobayashi (emeritus); Lawrence H. N. Lee (emeritus); Stuart T. McComas (emeritus); Victor W. Nee (emeritus); Robert C. Nelson; Timothy C. Ovaert; Samuel Paolucci; Francis H. Raven (emeritus); John E. Renaud; Mihir Sen; Steven B. Skaar; Albin A. Szewczyk (emeritus); Flint O. Thomas; Kwang-tzu Yang (emeritus)
Associate Professors:
Edmundo Corona; J. William Goodwine Jr.; Robert A. Howland; John W. Lucey (emeritus); James J. Mason; Joseph M. Powers; Steven R. Schmid; Michael M. Stanisic
Assistant Professors:
Alan P. Bowling; James E. Houghton (emeritus); Scott C. Morris; Glen L. Niebur; Ryan K. Roeder
Associate Professional Specialist:
Rodney L. McClain; Richard B. Strebinger
Assistant Professional Specialist:
John F. Koenigshof

Program of Studies. The Department of Aerospace and Mechanical Engineering offers programs of study which lead to degrees of bachelor of science and master of science in aerospace engineering and mechanical engineering, respectively; master of engineering for mechanical engineers; and doctor of philosophy.

Program in Aerospace Engineering. This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The aerospace program is designed to prepare those students interested in the design and operation of aircraft and space vehicles for entrance into a professional career. The curriculum, based on a solid foundation in mathematics, physics, chemistry and the engineering sciences, places emphasis on such basic aerospace disciplines as aerodynamics and fluid mechanics, orbital mechanics, and solid and structural mechanics, as well as such integrating disciplines as design, experimental methods and systems analysis. Technical specializations in the junior and senior year enable students to emphasize specific technical areas, including. design and manufacturing, thermal and fluid sciences, bioengineering, solid mechanics, materials, control and mechanical systems and computational engineering.

The aerospace engineering program uses laboratories in Fitzpatrick Hall of Engineering and in the Hessert Laboratory for Aerospace Research. The Hessert laboratories contain superior facilities for instruction and research.

Students are encouraged to participate in the activities of the student chapter of the American Institute of Aeronautics and Astronautics and to enter the national student paper competition conducted by the parent institute. Outstanding achievement in the aerospace program is recognized by membership in Sigma Gamma Tau, the national aerospace honor society.

Further details about the standard aerospace program, the aerospace London Program and electives can be found on the World Wide Web at www.nd.edu/~ame. These details include the program of study requirements for graduating classes prior to the Class of 2006; the program below pertains only to the Class of 2006 and beyond.

Aerospace Engineering Program Objectives. The program objectives are to prepare students for entrance into professional careers in the aerospace industry, government, research laboratories, the engineering discipline in general, and graduate school. This preparation builds on the personal interaction and communication skills that are already part of the overall Notre Dame liberal arts experience, and is further based on a solid foundation in mathematics, physics, chemistry and the engineering sciences. The curriculum places emphasis on basic topics in aerospace sciences, design and experimental methods. Some specialization in areas including fluid mechanics and aerodynamics, thermal sciences, space sciences, experimental aerodynamics, manufacturing and applied mathematics, may be obtained from technical specializations taken in the junior and senior years. The design content of the curriculum and the senior design experience emphasize overall system performance.

More specifically, the academic preparation has, as its objective, graduates who:

- Are familiar with multiple fields and types of professional practice—the kinds of things aerospace engineers do, the kinds of problems they solve, especially a breadth of familiarity with aerospace systems and designs that are enabled by embedded computing.
- Understand key scientific first principles of aerospace engineering, and are competent deriving, and using, algebraic relationships, as well as ordinary or partial differential equations for modeling or simulation of discrete and continuous aerospace systems by way of analytical and numerical treatment.
- Are aware of the essential function of common sensor types, and are experienced in acquiring digital data from a range of transducers; are able to compare, and gain insight from, a mix of analytical, numerical, and experimental results.
- Have a pragmatic outlook toward design and are able to factor into design a range of knowledge involving aerodynamics, structures, stability and control, materials, manufacturing processes, and tabulated data, as well as analytical, numerical, and experimental results; experienced with the integration of digital processing in design.
- Are capable of programming computers, including microprocessors, using C, C++, Matlab, and/or other similar languages; able to use CAD and other prepared software.
- Are able to communicate well and function effectively in design groups both in leadership and support roles.
- Have a grasp of the impact of technology on the welfare of individuals and groups; and, consistent with the perspective of Catholic character, broadly defined, apply high ethical and professional standards to the practice of engineering.

Are able to engage in lifelong, independent learning; and a significant number carry on for further graduate study and are recognized as among the best aerospace engineering graduates in the country.

First Year of Studies
First-year students intending to major in aerospace engineering when they become sophomores will find first-year course requirements on the first page of the College of Engineering section.

Sophomore Year
First Semester

MATH 225. Calculus III	3.5
PHYS 132. General Physics II	4
AME 225. Mechanics I	3
AME 240. Introduction to Aeronautics	3
Arts and Letters course+	3
	16.5

Second Semester

MATH 228. Introduction to Linear Algebra and Differential Equations	3.5
AME 226. Mechanics II	3
AME 238. Solid Mechanics	4
AME 327. Thermodynamics	3
AME 250. Measurements and Data Analysis or AME 341. Computer Aided Design and Manufacturing	3
	16.5

Junior Year

First Semester

AME 301. Differential Equations, Vibrations and Controls I	3
AME 250. Measurements and Data Analysis or AME 341.Computer Aided Design and Manufacturing	3
AME 346. Aerospace Structures	3
AME 330. Fluid Mechanics	3
Arts and Letters course+	3
	15

Second Semester

AME 302. Differential Equations, Vibrations and Controls II	3
AME 342. Aerodynamics Laboratory	4
AME 360. Compressible Aerodynamics	3
AME 439. Heat Transfer	3
Arts and Letters course+	3
	16

Senior Year

First Semester

AME 440. Flight Mechanics and Introduction to Design	3
AME 443. Aerospace Dynamics	3
AME 454. Gas Turbines and Propulsion	3
Technical Specialization+	3
Arts and Letters course+	3
	15

Second Semester

AME 366. Orbital and Space Dynamics	3
AME 441. Aerospace Design	4
Technical Specialization/Prof. Development	3
Technical Specialization	3
Arts and Letters course+	3
	16

Total for the four years: 129 semester hours.

+ *See "Arts and Letters Core" on the first page of the College of Engineering section.*

**A list of approved AME and technical specialization courses is available on the department Web site.*

The most current information for the degree program course requirements is available on the department Web site: (www.nd.edu/~ame/).

The Program in Mechanical Engineering. This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The department offers a well-rounded program at the bachelor's level. The curriculum is built on a sound foundation in mathematics, physics, chemistry and the engineering sciences. In the undergraduate curriculum the student may obtain, by suitable selection of elective courses, a program suited to enable him or her to specialize in a given sequence or to prepare as a generalist. Elective course sequences are available in aerospace, design and manufacturing, thermal and fluid sciences, bioengineering, solid mechanics, materials, control and mechanical systems and computational engineering.

To prepare for today's changing technological world, the program requires a continual use of a computer in all of its courses.

Finally, for professional growth during formative years as engineers in training, students are encouraged to participate in the activities of the student chapter of the American Society of Mechanical Engineers. Outstanding achievement in the mechanical engineering program is recognized by membership in Pi Tau Sigma, the national mechanical engineering honor society.

Further details about the mechanical engineering program, the London Program and electives can be found on the World Wide Web at www.nd.edu/~ame. These details include the program of study requirements for graduating classes prior to the Class of 2006; the program below pertains only to the Class of 2006 and beyond.

Mechanical Engineering Program Objectives. The general program objectives are to prepare students for entrance into professional careers in industry, government, research laboratories, the engineering discipline in general, and graduate school. This preparation builds on the interaction and communication skills that are already part of the overall Notre Dame liberal arts experience, and is further based on a solid foundation in mathematics, physics, chemistry, and the engineering sciences. The curriculum places emphasis on basic topics in mechanical-engineering sciences, design and experimental methods. Some specialization in areas may be obtained from technical electives taken in the junior and senior years.

More specifically, the academic preparation has as its objective graduates who:

- Are familiar with multiple fields and types of professional practice, the kinds of things mechanical engineers do, the kinds of problems they solve, especially a breadth of familiarity with newer systems and designs such as those that are enabled by embedded computing.
- Understand key scientific first principles of mechanical engineering, and are competent deriving, and using algebraic relationships, as well as ordinary or partial differential equations for modeling or simulation of discrete and continuous mechanical systems by way of analytical and numerical treatment.
- Are aware of the essential function of common sensor types, and are experienced in acquiring digital data from a range of transducers; are able to compare, and gain insight from, a mix of analytical, numerical and experimental results.
- Have a pragmatic outlook toward design and are able to factor into design a range of knowledge involving materials, manufacturing processes, and tabulated data, as well as analytical, numerical, and experimental results; experienced with the integration of digital processing in design.
- Are capable of programming computers, including microprocessors, using C, C++, Matlab, and/or other similar programming languages; able also to use CAD and other prepared software.
- Are able to communicate well, both orally and in writing, and function effectively in design groups both in leadership and support roles.
- Have an understanding of the impact of technology on the welfare of individuals and groups; and, consistent with the perspective of Catholic character, broadly defined, apply high ethical and professional standards to the practice of engineering.
- Are able to engage in lifelong, independent learning; and a significant number carry on for further graduate study and are recognized as among the best mechanical engineering graduates in the country.

First Year of Studies

First-year students intending to major in mechanical engineering when they become sophomores will find first-year course requirements on the first page of the College of Engineering section.

Sophomore Year

First Semester

MATH 225. Calculus III	3.5
PHYS 132. General Physics II	4
AME 225. Mechanics I	3
AME 230. Introduction to Mechanical Engineering	3
Arts and Letters course+	3
	16.5

Second Semester	
MATH 228. Introduction to Linear Algebra and Differential Equations	3.5
AME 226. Mechanics II	3
AME 238. Solid Mechanics	4
AME 250. Measurements and Data Analysis or AME 341. Computer Aided Design and Manufacturing	3
AME 327. Thermodynamics	3
	16.5

Junior Year

First Semester	
AME 301. Differential Equations, Vibrations and Controls I	3
AME 250. Measurements and Data Analysis or AME 341 Computer Aided Design and Manufacturing	3
AME 330. Fluid Mechanics	3
AME 340. Design of Machine Elements	3
Arts and Letters course+	3
	15
Second Semester	
AME 302. Differential Equations, Vibrations and Controls II	3
AME 439. Heat Transfer	3
AME 344. Design Methodology	3
EE 224. Introduction to Electrical Engineering	4
Arts and Letters course+	3
	16

Senior Year

First Semester	
CHEG 225. Science of Engineering Materials	3
AME 470. Senior Design Project	4
AME 430. Mechanisms and Machines	3
Technical Elective*	3
Arts and Letters course+	3
	16
Second Semester	
AME Elective*	3
AME Elective*	3
AME Elective*	3
Technical Elective*	3
Arts and Letters course+	3
	15

+ *See "Arts and Letters Core" on the first page of the College of Engineering section.*

**A list of approved AME and general technical electives is available on the department Web site.*

The most current information for the degree program course requirements is available on the department Web site: (www.nd.edu/~ame/).

Total for the four years: 129 semester hours.

Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week and laboratory and/or tutorial hours per week and credits each semester are in parentheses.

225. Mechanics I
(3-0-3) Staff
Prerequisites: MATH 126, PHYS 131, EG 111 or equivalent.
Introduction to systems of forces and couples. Vector mechanics, equilibrium of rigid bodies. Internal forces and moments, trusses and beams, distributed loads and properties of areas, friction and virtual work, kinematics and kinetics of particle motion, systems of particles. Fall.

226. Mechanics II
(3-0-3) Staff
Prerequisites: AME 225, MATH 225.
Introduction to Newtonian dynamics. Kinematics and kinetics (energy, linear and angular momenta) of particles, systems of particles and rigid bodies. Spring.

230. Introduction to Mechanical Engineering
(3-1-3) Staff
An introduction to the discipline of mechanical engineering. Application and integration of the varied mechanical engineering subdisciplines to practical case studies. Fall.

238. Solid Mechanics
(3-2-4) Staff
Prerequisites: AME 225, MATH 225.
An introduction to theoretical and experimental aspects of the mechanics of deformable solids. Concepts of stress, strain, stability, and deformation of simple structures are introduced. Experimental exercises may entail use of embeddable microprocessors. Spring.

240. Introduction to Aeronautics
(3-0-3) Staff
Prerequisites: MATH 126, PHYS 131.
An introduction to the atmosphere, fundamental concepts in fluid mechanics and airplane aerodynamics. Application of the principles of mechanics to aircraft flight performance, stability, and control and design. Fall.

250. Measurements and Data Analysis
(1-2-2) Corona, Dunn, Ovaert
Introduction to experimental methods used in aerospace and mechanical engineering, including basic instrumentation, data acqusition and data analysis techniques. Embeddable microprocessors may be used for data acquisition and/or control. Fall and spring.

301. Differential Equations, Vibrations, and Controls I
(3-1-3) Staff
Prerequisites: MATH 228
First of a two-course sequence that introduces methods of differential-equation solution together with common engineering applications in vibration analysis and controls. Includes second-order, linear differential equations, feedback control, and numerical solutions to systems of ordinary differential equations. Fall.

302. Differential Equations, Vibrations, and Controls II
(3-1-3) Staff
Prerequisite: AME 301
Systems of nth-order differential equations, mechanical vibrations, linear feedback s-plane controls analysis, frequency response analysis, partial differential equations. Spring.

327. Thermodynamics
(3-0-3) Staff
Prerequisite: MATH 225
Basic concepts of thermodynamics. The First Law of Thermodynamics. Work, heat, properties of substances and state equations. The Second Law of Thermodynamics. Applications to engineering systems. Student and/or instructor-conducted experiments may entail use of embeddable microprocessors. Spring.

328. Intermediate Thermodynamics
(3-0-3) Staff
Prerequisite: AME 327.
This course will expand the student's knowledge and interest into moist air processes, psychrometrics, gas mixtures and real gas behavior. The course will also present the basics of chemical equilibrium and chemical reactions. Energy-related problems will pose the focus; for example, problems including vapor and gas cycle analysis.

330. Fluid Mechanics
(3-0-3) Staff
Prerequisites: AME 226, 327, and MATH 228
A basic course in fluid mechanics. Topics include mathematics of fluids, Euler N, S Bernoulli's equation, control volumes, differential analysis, dimensional analysis and dynamic similarity, aerodynamics, boundary layers, and turbulence. Fall.

335. Intermediate Dynamics
(3-0-3) Howland
Prerequisites: AME 226, MATH 228.
Kinematics and dynamics of rigid bodies in three dimensions, Lagrange's equations, and linear vibrations.

340. Design of Machine Elements
(3-0-3) Staff
Prerequisites: AME 238.
Static and fatigue failure theories. Theory, design and selection of gearing, power transmitting shafts, rolling element bearings, journal bearings, fasteners, springs, brakes, and clutches. Fall.

341. Computer-Aided Design and Manufacturing
(1-4-3) Staff
Principles of engineering-graphic communication: visualization, sketching, orthographic projection, principal and auxiliary projections, 3D surfaces, and feature-based design. Geometric dimensioning and tolerancing, computer-integrated manufacturing, and rapid prototyping. Fall and Spring.

342. Aerodynamics Laboratory
(1-4-3) Thomas, Nelson, Morris
Prerequisite: AME 250.
Corequisite: AME 360.
Use and operation of subsonic wind tunnels, flow velocity, pressure and strain gauge measurements, data acquisition and analysis, embedded microprocessors with emphasis on interpretation of aerodynamic flow phenomena. Spring.

343. Engineering Economy
(3-0-3) Staff
A study of methods for determining the comparative financial desirability of engineering alternatives, including the use of time, various levels of cost/revenue and interest rates as parameters in the evaluation.

344. Design Methodology
(3-0-3) Staff
Modeling and analysis of mechanical systems. Automated design decision process, introduction to statistical methods, material engineering, requirements definition and product specifications. Spring.

346. Aerospace Structures
(3-0-3) Staff
Prerequisite: AME 238.
Study of the basic principles and methods of structural analysis of lightweight structures. Introduction to stress, deformation, yielding, buckling, and fatigue/fracture analysis of truss and semi-monocoque structures, and mechanical behavior of aerospace structural methods. Fall.

360. Compressible Aerodynamics
(3-0-3) Staff
Prerequisite: AME 334 or AME 330.
An intermediate course of the study of the dynamics and thermodynamics of compressible flow for both internal and external geometrics, including boundary layer effects. Applications of compressible flow principles to propulsive nozzles, flight simulation facilities, and supersonic airfoil problems. Spring.

366. Orbital and Space Dynamics
(3-0-3) Howland
Prerequisite: AME 226.
The one- and two-body problems: geometrical elements and time dependence. Orbital determination. Linear orbits and regularization. Orbital transfer. The n-body problem; various forms of the three-body problem, including the circular restricted case, its "equilibrium" solutions and their stability. Spring.

430. Mechanisms and Machines
(3-0-3) Staff
Prerequisites: AME 226, MATH 228
A course teaching the analysis and synthesis of planar, spherical and spatial mechanisms. Topics include: vectors, complex numbers and the analysis of planar mechanisms, design of cams, gear tooth geometry and the analysis of transmissions, synthesis of planar mechanisms, direction cosine matrices and the analysis of spherical mechanisms, homogeneous transformations, and the analysis of spatial mechanisms. Fall.

435. Reliability Engineering
(3-0-3) Staff
Prerequisite: MATH 225.
Topics covered include statistical concepts such as population, probability distribution, mean, variance, samples and data treatment; also, statistical process control including process control charts and process capability; introduction to design of experiments and Taguchi methods. Fall.

439. Heat Transfer
(3-0-3) Staff
Prerequisite: AME 334 or AME 330.
An introductory course covering three modes of heat transfer: steady and unsteady conduction, elementary boundary layer analysis for laminar and turbulent convection and the basic theory of radiation. Spring.

440. Flight Mechanics and Introduction to Design
(3-0-3) Corke
Prerequisite: AME 360.
Corequisite: AME 346
The fundamentals of flight performance are developed. Primary emphasis will be on examining how configuration design parameters affect aircraft performance. Students are introduced to aircraft preliminary design methodology. Fall.

441. Aerospace Design
(2-4-4) Corke
Prerequisite: AME 440.
Team design project with application to an aerospace system development. Includes topics in all associated technologies, design methodology, standards and engineering ethics. Spring.

443. Aerospace Dynamics
(3-0-3) Nelson
Prerequisites: AME 226, AME 302.
Mechanics and equations of motion. Aerodynamics forces and motions; longitudinal, lateral, and roll motions. Introduction to autopilot design. Fall.

446. Finite Element Methods for Structural Analysis
(3-0-3) Staff
Prerequisite: AME 238.
An introduction to matrix methods in structural analysis and matrix methods for linear systems. The finite element stiffness method is applied to static, dynamic, and stability analysis of lightweight structures. Spring.

450. Computational Fluid Dynamics
(3-0-3) Thomas
Prerequisite: AME 334 or AME 330.
An introduction to the fundamentals of computational aerodynamics/fluid mechanics. Numerical techniques are developed and applied to the solution of several practical fluid mechanics and aeronautics problems. Fall.

454. Gas Turbines and Propulsion
(3-0-3) Staff
Prerequisite: AME 334 or AME 330.
The mechanics and thermodynamics of air-breathing propulsion devices. The mechanics of various space propulsion systems are also presented, including an introduction to rocket propulsion. Fall.

465. Space Systems and Analysis
(3-0-3) Staff
Prerequisite: Junior or senior standing in engineering.
Missions, spacecraft dynamics, attitude determination and control, space environment, spacecraft power, telecommunications, avionics, data handling/processing, and other topics that may include configuration, load determination, and structure and thermal control.

466. Engineering Analysis of Manufacturing Processes
(3-0-3) Staff
Prerequisites: AME 238, CHEG 225.
A senior elective course dealing with the application of engineering analysis to casting, forming machining and joining processes, as well as other advanced manufacturing processes.

469. Introduction to Robotics
(3-0-3) Goodwine, Bowling
Prerequisite: \AME 301.
Kinematics of 2-D and 3-D robots; statics and dynamics; design considerations; actuators; sensors; control fundamentals; artificial intelligence; and vision systems. Experiments in the robotics laboratory demonstrate the fundamentals of robotics.

Alan Bowling, assistant professor of aerospace and mechanical engineering

470. Senior Design Project
(2-4-4) Stanisic, Batill
Prerequisite: Senior standing.
A course that provides a comprehensive team-oriented, project-based design of a selected mechanical system or process. Projects involve design specification development, engineering design, documentation, and prototype fabrication. Projects are assessed by industrial reviewers. Fall.

480. Advanced Design Project
(V-V-V) Staff
Prerequisites: AME 470 and approval of the chair.
A course to provide a student with the opportunity to pursue a more advanced design topic or in-depth project which was started in AME 470. Requires department approval at the beginning of the senior year.

498. Special Studies
(V-V-V) Staff
Prerequisites: Senior standing and approval of the chair.
Individual or small group study under the direction of a faculty member in an undergraduate subject not currently covered by any University course.

499. Undergraduate Research
(V-V-V) Staff
Prerequisite: Approval of chair.
A research project at the undergraduate level under the supervision of a faculty member. Fall and spring.

A number of introductory graduate level courses, described in the *Graduate School Bulletin of Information* and on the department Web site, are open to advanced undergraduates, with the permission of the department chair, to satisfy upper level electives.

Chemical and Biomolecular Engineering

Chair:
Mark J. McCready
Keating-Crawford Professor of Chemical Engineering:
Roger A. Schmitz
Bayer Professor of Chemical Engineering:
Hsueh-Chia Chang
Keating-Crawford Professor of Chemical Engineering:
Joan F. Brennecke
Professors:
Jeffrey C. Kantor; David T. Leighton Jr.; Mark J. McCready; Paul J. McGinn; Albert E. Miller; Mark A. Stadtherr; William C. Strieder; Eduardo E. Wolf
Associate Professors:
Davide A. Hill; Edward J. Maginn
Assistant Professors:
Agnes E. Ostafin; Andre F. Palmer
Research Professors:
Evgeny Demekhin; Alexander S. Mukasyan
Assistant Research Professor:
Sudhir Aki
Professional Specialist:
Salma R. Saddawi

Program of Studies. The Department of Chemical and Biomolecular Engineering offers programs of study leading to the degrees of bachelor of science in chemical engineering, master of science in chemical engineering, and doctor of philosophy. The program leading to the bachelor of science degree is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

The traditional role for chemical engineers of providing the principal technical guidance for the chemical and petroleum industries has been greatly augmented in recent years. Chemical engineers now direct the advancement and utilization of technology for the food processing and consumer products industries and are playing increasing roles in the manufacture of the highest density computer chips and in the invention of advanced drug delivery systems. In addition to creating remediation strategies, chemical engineers contribute to the prevention of deleterious impact of society on the environment by the development of new "green" process technologies that eliminate the use of dangerous solvents. They are the leaders in the field of "sustainability" which is the implementation of energy sources and raw material supplies that can sustain humankind indefinitely. In all of these areas, complex processes involving chemical changes of matter occur and, as such, sound training in chemistry, physics, mathematics, and allied applied sciences are prerequisites to resolving the challenges posed by these complex systems.

The undergraduate program at Notre Dame is notable for its combination of a strong fundamental focus in chemical engineering courses with a broad humanities and science education provided in courses outside of chemical engineering. The science and humanities courses prepare students both for study of chemical engineering and to understand the complex scientific, social, and moral issues of the world today. Our intention in emphasizing fundamentals is to develop students' intellect and to equip them with enduring knowledge in chemical engineering and related fields. Thus, our undergraduate chemical engineering curriculum provides students with not only a preparation for a career as chemical engineer, but for a lifetime of learning and a lifelong career in areas that may include law, medicine, or business.

University of Notre Dame Undergraduate Program Goals: Students who have graduated in Chemical Engineering at Notre Dame have pursued, successfully, a wide range of career paths. The faculty believes that this has resulted from the interests of students who enter our program and is facilitated by our emphasis on fundamental aspects of chemical engineering. Thus consistent with the mission of the University, the Department of Chemical and Biomolecular Engineering program seeks to develop students who:

1. Pursue knowledge and commensurate understanding and critically evaluate the consequences of these.
2. Communicate clearly and effectively.
3. Demonstrate proficiency in the art and science of chemical engineering with a strong understanding of the fundamental principles of pure and engineering sciences on which chemical engineering practice is based.

4. Appreciate their social and moral responsibilities both within their careers in engineering and through service in their communities.
5. Understand how chemical engineering connects with other major disciplines to produce the goods and services needed by society.

Within the chemical engineering degree program, students can use their electives to construct course sequences in Materials, Environmental Chemical Engineering and Biomolecular Engineering. A suggested course sequence for students interested in going to medical school is also available.

More than one-third of the chemical engineering undergraduates participate in research activities with Faculty and Graduate students at some time in their careers in such areas as advanced materials, ionic liquids as environmentally benign solvents, biomaterials, microfluidic devices, catalysis, fuel cells and drug delivery techniques.

Further details about the chemical engineering program may be found on the World Wide Web at www.nd.edu/~chegdept. These details include the program of study requirements for graduating classes prior to the Class of 2007. The program below pertains only to the Class of 2007 and beyond.

FIRST YEAR OF STUDIES

First-year students intending to major in chemical engineering when they become sophomores will find first-year course requirements on the first page of the College of Engineering section.

Sophomore Year

First Semester

MATH 225. Calculus III	3.5
CHEM 223. Organic Chemistry I	3
CHEM 223L: Organic Chemistry Lab I	1
PHYS 132. General Physics II	4
CHEG 255. Introduction to Chemical Engineering Analysis	3
Arts and Letters Course+	3
	17.5

Second Semester

CHEM 224. Organic Chemistry II	3
MATH 228. Introduction to Linear Algebra and Differential Equations	3.5
CHEG 256. Chemical Engineering Thermodynamics	4
CHEG 258. Computer Methods in Chemical Engineering	3
Arts and Letters course+	3
	16.5

Junior Year

First Semester

MATH 325. Differential Equations	3
CHEM 333. Analytical Chemistry	2
CHEM 333L: Analytical Chemistry Lab	2
CHEG 225. Science of Engineering Materials	3
CHEG 355. Transport Phenomena I	3
Arts and Letters course+	3
	16

Second Semester

CHEM 324. Physical Chemistry	3
CHEG 356. Transport Phenomena II	3
CHEG 358. Chemical Engineering Laboratory I	3
CHEG 438. Chemical Process Control	3
Elective	3
Arts and Letters course+	3
	18

Senior Year

First Semester

CHEG 459. Chemical Engineering Laboratory II	3
CHEG 443. Separation Processes	3
CHEG 445. Chemical Reaction Engineering	3
Engineering/Chemistry Elective*	3
Chemical Engineering Elective*	3
	15

Second Semester

Chemical Engineering Elective*	3
CHEG 448. Chemical Process Design	3
Technical Elective*	3
Engineering/Chemistry Elective *	3
Arts and Letters course+	3
	15

** All electives are selected from a list available in the department office or found on the department Web site.*

+ See "Arts and Letters Core" on the first page of the College of Engineering section.

Total for the four years: 132 semester hours.

Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week and laboratory and/or tutorial hours per week and credits each semester are in parentheses.

225. Science of Engineering Materials
(3-0-3) Mukasyan
Prerequisite: CHEM 116, 118, or 122.
This is an introductory course that examines the relationship between the structure, processing, and properties of engineering materials. Common engineering materials, including steel, concrete, ceramics, and polymers are discussed. Mechanical, chemical, electrical, and magnetic properties of various materials are examined. The process dependence of microstructural development and defects levels are described.

255. Introduction to Chemical Engineering Analysis
(3-0-3) Ostafin
Prerequisites: CHEM 116, 118, or 122.
This is a foundation course in which the students learn to apply the concepts of material and energy balances to problems involving chemical processes, biological systems and environmental phenomena. Within this context, they learn problem-solving techniques and acquire a working knowledge of phase equilibria, physical properties, and computer applications.

256. Chemical Engineering Thermodynamics
(3-3-4) Maginn
Prerequisite: CHEG 255.
The course provides an introduction to modern applied thermodynamics, with a focus on aspects relevant to chemical engineers. It begins with a review of the first law energy balance, followed by the development of the second law entropy balance. Thermodynamic constitutive equations for gases and liquids are developed from a molecular-level perspective, followed by applications involving thermodynamic cycles and energy conversion. The second half of the course concerns stability, thermodynamics of mixtures, and phase and chemical equilibrium.

258. Computer Methods in Chemical Engineering
(3-0-3) Palmer
Prerequisite: CHEG 255.
Algorithms for solving algebraic (e.g. Gaussian Elimination, PLU decomposition, etc.) and differential equations (e.g. Runge-Kutta, Shooting methods) are derived and implemented using Matlab. Statistics and error analysis constitute a significant part of the course.

290. Career Choices for Engineers
(1-0-1) Staff
A seminar series featuring selected speakers who are employed or consult with high tech business enterprises of both national and global involvement. The presentations and open symposium format will emphasize business ethics, competitive pressures, people skills and most importantly, career opportunities for engineering graduates.

355. Transport Phenomena I
(3-0-3) Leighton
Prerequisite: CHEG 256.
Basic conservation principles of energy, mass, and momentum are used to derive the integral and differential forms of the transport equations. These equations are used to solve fluid flow problems of both fundamental and practical interest.

356. Transport Phenomena II
(3-0-3) McCready
Prerequisite: CHEG 355.
Integral and differential transport equations are applied to the solution of heat and mass transfer problems of interest to chemical engineers.

358. Chemical Engineering Laboratory I
(1-4-3) Saddawi
Prerequisite: CHEG 355.
Chemical engineering laboratory courses are comprised of experiments that cover most of the major subject areas of chemical engineering. The rationale for combining all of the topics into two separate courses, as opposed to distributing them into the different lecture courses, is to provide a focused learning experience emphasizing experimental techniques to observe fundamental behavior, understanding of the phenomena in terms of the appropriate theory and experience at technical report writing. Formal and informal oral presentation skills are also an important part of the courses.

438. Chemical Process Control
(3-0-3) Stadtherr
Prerequisite: CHEG 355.
While the idealization of chemical processes is that they are operated at steady-state, they are in fact usually dynamic (unsteady state). Process feed compositions may change slightly, ambient conditions may change, pipe leaks may develop, steam pressures may vary, etc. There are any number of such disturbances that may cause the process to deviate from its desired steady-state. In some cases, such deviations may be catastrophic, in other cases a severe loss of product quality may be caused. Thus process control devices are installed that detect deviations from the desired steady-state and attempt to correct them. In this course, students will be introduced to the analysis of chemical process dynamics, and to the design and analysis of process control systems.

443. Separation Processes
(3-0-3) Hill
Prerequisite: CHEG 356.
This course demonstrates the application of the principles of phase equilibria, transport processes and chemical kinetics to the design and characterization of stagewise and continuous separation processes. Both graphical and rigorous numerical techniques are used, and the general procedures applicable to different specific processes are emphasized. Example problems are drawn from the petroleum, chemical, food, biochemical and electronic materials processing industries.

445. Chemical Reaction Engineering
(3-0-3) McCready
Prerequisite: CHEG 356.
The basic concepts of chemical rate processes are applied to the theory of the design and operation of the various types of commercial reactors for both noncatalytic and catalytic reactions. Topics covered include mole balances, rate laws and stoichiometry, collection and analysis of rate data, multiple reactions, isothermal and nonisothermal reactor design, catalysis and catalytic reactors.

Andre F. Palmer, assistant professor of chemical engineering

448. Chemical Process Design
(3-0-3) Maginn
Prerequisites: CHEG 443, 445.
This course represents a capstone in the chemical engineering curriculum. In this course students will have the opportunity to apply the basic concepts learned in previous courses to the design and analysis of a chemical processing system. This will be done primarily through the design project. Supporting material to be covered in lectures includes the following: computer-aided design (process simulation), economic analysis, process safety, flowsheet synthesis (conceptual design), and decision making analysis (optimization).

458. Chemical Process Simulation and Optimization
(3-0-3) Stadtherr
Prerequisite: CHEG 438.
This course provides an overview of the computational methodologies used for chemical process simulation and optimization. Topics include partitioning and tearing, nonlinear equation solving, and nonlinear programming.

459. Chemical Engineering Laboratory II
(1-4-3) Saddawi
Prerequisites: CHEG 356, 358.
Chemical engineering laboratory courses are composed of experiments that cover most of the major subject areas of chemical engineering. The rationale for combining all of the topics into two separate courses, as opposed to distributing them into the different lecture courses, is to provide a focused learning experience emphasizing experimental techniques to observe fundamental behavior, understanding of the phenomena in terms of the appropriate theory and experience at technical report writing. Formal and informal oral presentation skills are also an important part of the courses.

461. Structure of Solids
(3-0-3) McGinn
Prerequisite: CHEG 225.
This class seeks to provide students with an understanding of the structure of solids, primarily as found in metals, alloys, and ceramics applied in technological applications. The structure of crystalline solids on the atomic level as well as the microstructural level will be discussed. Imperfections in the arrangements of atoms will be described, especially as regards their impact on properties. The study of structure through X-ray diffraction will be a recurring theme. A sequence of powder diffraction laboratory experiments (four to five class periods) also will be included.

463. Laboratory Techniques in Materials Science
(0-4-1) McGinn
Prerequisite: CHEG 225.
This course is intended for Junior Chemical Engineering majors who are participating in the materials certificate program. The goal of the course is to introduce students to instrumentation they will likely use in the course of their senior thesis research. Laboratory sequences last from two to four weeks. A laboratory report is written for each lab as per instructions from each professor.

472. Topics: Ecology and Environment
(3-0-3) Stadtherr
Prerequisites: CHEG 356, 438.
This course covers various topics pertaining to Earth's natural (ecological and biogeochemical) systems and the effects of disturbances or imbalances, particularly those caused by human/industrial activities. Based on chemical engineering fundamentals embodied in chemical reaction engineering, process dynamics, and transport phenomena, the principal topics center on population and ecosystem dynamics, and on the fate and transport of chemicals in the environment. Examples and applications are drawn from such subjects as the endangerment or extinction of species, atmospheric greenhouse gases, pollutant dispersion, ozone pollution in the troposphere and depletion in the stratosphere, acid rain, and so on. The course makes extensive use of methods of mathematical modeling, nonlinear dynamics, and computer simulations.

473. Environmental Design
(3-0-3) Brennecke
Prerequisites: CHEG 258, 356.
The goals of this course are to explore how to design and operate chemical processes so that we avoid or decrease the amount of pollutants that are released into the environment. Thus, this is essentially a course in pollution prevention. In the course, we identify and apply chemical engineering principles learned in previous classes (thermodynamics, phase equilibria, transport, reaction engineering) to environmental problems. In addition to normal lectures, discussions and homeworks, the course is comprised of a series of case studies that compare the design and operation of chemical processes using conventional technology versus new technology that incorporates various principles of pollution prevention.

481. Biomedical Engineering Transport Phenomena
(3-0-3) Palmer
Prerequisite: CHEG 356.
This course brings together fundamental engineering and life science principles, and provides a focused coverage of key concepts in biomedical engineering transport phenomena. The emphasis is on chemical and physical transport processes with applications toward the development of drug delivery systems, artificial organs, bioartificial organs, and tissue engineering.

482. Biomaterials Engineering
(3-0-3) Ostafin
Prerequisites: CHEG 225, 356.
Biomaterials engineering is the application of engineering principles to design, develop, and analyze materials that involve biological molecules. These may be materials of biological origin that are used in medical, biological, or chemical applications, and materials of chemical origin that are used with biological systems or their components. In this course you learn about the basic principles involved in the choice of material properties, the nature of the interaction of biological materials with their surroundings, and modern applications in science, medicine and engineering. Issues relating to marketing, packaging and storage, regulation, and ethics will also be discussed. Students will have an opportunity to apply mathematical-based engineering analysis of complex biomaterials systems.

484. Bioprocess Engineering
(3-0-3) Ostafin
Prerequisites: CHEG 256, 356.
Bioprocess engineering is the application of engineering principles to design, develop, and analyze processes that use biocatalysts. These may be in the form of a living cell, its substructures, or their chemical components. In this course you learn concepts of cellular biology, and be introduced to mathematical-based engineering analysis of complex biological systems. By the end of this course you should be able to understand basic structure and function of cells, homogeneous and heterogeneous enzyme kinetics, the regulation of cell growth, the design and operation of bioreactors, recovery and characterization of products, and methods in genetic engineering and molecular cloning.

499A. Undergraduate Research
(V-V-3) Staff
Prerequisites: CHEG 499C and approval of advisor.
A graded written progress report describing the research project and results is required. Fall and spring.

499B. Undergraduate Thesis
(V-V-2) Staff
Prerequisites: CHEG 499A and approval of advisor.
A graded research project at the undergraduate level under the supervision of a faculty member. A substantial written document describing the research project, results and conclusions is required. Fall and spring.

499C. Undergraduate Research
(V-V-1) Staff
Prerequisite: Approval of advisor.
A one-credit S/U research project at the undergraduate level under the supervision of a faculty member. This course must be completed before enrolling in the three-credit graded CHEG 499A. Fall and spring.

The following graduate courses, described in the *Graduate School Bulletin of Information,* are also open to advanced undergraduates.

542. Mathematical Methods Engineering I
553. Advanced Chemical Engineering Thermodynamics
544. Transport Phenomena I
546. Advanced Chemical Reaction Engineering

Civil Engineering and Geological Sciences

Massman Chair:
Peter C. Burns
Robert M. Moran Professor of Civil Engineering:
Ahsan Kareem
Professors:
Peter C. Burns; Jeremy B. Fein;
Robert L. Irvine (emeritus); Sydney Kelsey (emeritus); Lenneth R. Laurer (emeritus);
Patricia A. Maurice; Stephen E. Silliman;
James I. Taylor (emeritus); Erhard M. Winkler (emeritus)
Associate Professors:
Lloyd H. Ketchum Jr.; David J. Kirkner;
Yahya C. Kurama; Jerry J. Marley (emeritus);
Clive R. Neal; J. Keith Rigby Jr.;
Rev. James A. Rigert, C.S.C. (emeritus);
Joannes J.A. Westerink
Assistant Professors:
Tracy L. Kijewski-Correa; Robert Nerenberg;
Lynn A. Salvati; Jeffrey W. Talley;
Wilasa Vichit-Vadakan; Jennifer R. Woertz
Associate Professional Specialist:
Jinesh C. Jain

Vision and Mission. The Department of Civil Engineering and Geological Sciences (CE/ENVG) aspires to be preeminent nationwide in our selected research and educational focus areas, to be ranked in the top quartile of civil engineering and environmental geoscience programs in the United States, to have global reach and impact in education and research, and to promote positive contributions to society in the Catholic tradition. CE/ENVG strives to provide a stimulating and unique interdisciplinary environment for learning and research by blending traditional disciplines of engineering and science. CE/ENVG offers outstanding educational programs for those aspiring to contribute as leaders in the fields of Civil Engineering, Environmental Engineering, and Environmental Geosciences. CE/ENVG's educational objective is to provide students with the knowledge, skills, vision and ethical basis to contribute as leaders in design, construction and protection of our civil infrastructure, and understanding, management and remediation of the environment.

Program of Studies. The Department of Civil Engineering and Geological Sciences offers programs of study leading to the degrees bachelor of science in civil engineering, bachelor of science in environmental geosciences, master of science in civil engineering, master of science in geological sciences, master of science in environmental engineering, master of science in bioengineering and doctor of philosophy.

Program in Civil Engineering. This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The department presents a well-rounded program for the bachelor's degree with the first two years devoted primarily to the basic principles of science and engineering. The third and fourth years are devoted to courses in the basic areas of civil engineering — structural analysis and design, hydraulics and hydrology, water supply and wastewater disposal, materials of construction, geotechnical engineering and transportation engineering. A student may emphasize a particular area of interest by selecting either the water re-source/environmental sequence or the structures sequence and by the careful use of elective courses. Civil engineering electives in the senior year may be regular courses or individualized directed study or research courses.

Most courses in the program are prescribed for all civil engineering students so that each student receives a firm foundation in the many basic disciplines comprising the broad field of civil engineering. This is especially desirable, for often in the course of professional development the civil engineer is asked to coordinate the planning, design and construction of highly complex systems and must utilize many or all of these disciplines.

The department has excellent facilities for research available to both graduate and undergraduate students. These facilities include a structural dynamics/structural control laboratory; a materials testing and structural research laboratory; a groundwater hydrology field laboratory; a number of analytical laboratories for water, wastewater and hazardous waste treatment; and a computing room.

The professional aspects of civil engineering are emphasized and promoted by the activities of a student chapter of the American Society of Civil Engineers, in which all students of the department are eligible to participate.

Further details about the civil engineering and environmental geosciences programs may be found on the World Wide Web at www.nd.edu/~cegeos.

First Year of Studies
First-year students intending to major in civil engineering when they become sophomores will find first-year course requirements on the first page of the College of Engineering section.

Sophomore Year
First Semester

MATH 225. Calculus III	3.5
PHYS 132. General Physics II	4
CE 225. Mechanics I	3
CE 242. Methods of Civil Engineering	4
	14.5

Second Semester

MATH 228. Introduction to Linear Algebra and Differential Equations	3.5
CE 231. Probabilistic and Statistical Meth	3
AME 238. Mechanics of Solids	4
CE 262. Engineering Geology	3
Arts and Letters*	3
	16.5

Junior Year
First Semester

MATH 325. Differential Equations	3
CE 336. Intro to Struc. Engrg.	3
CE 369. Intro to Env. Engrg.	3
CE 341. Computational Methods	3
Arts and Letters*	3
	15

Second Semester

CE 335. Materials	4
CE 351. Intro Geotech Engrg	4
CE 356. Structural Analysis (Opt A)**	(3)
CE 352. Water Treat and Chemistry (Opt B)**	(3)
AME 330. Fluid Mechanics	3
Arts and Letters*	3
	17

Senior Year
First Semester

CE 446. Hydraulics	3
CE 486. Reinf. Concrete Design (Opt A)**	(4)
CE 444. Groundwater Hydrology (Opt B)**	(4)
Civil Engineering Elective	3
Free Elective	3
Arts and Letters*	3
	16

Second Semester

CE 440. Transportation	3
CE 466. Structural Steel Design (Opt A)**	(4)
CE 443. Wastewater Des. (Opt B)**	(4)
Civil Engineering Elective	3
Technical Elective	3
Arts and Letters*	3
	16
Total degree required credits	130

**Note: The University Arts and Letters requirement is 24 credit hours. This consists of: Composition and Literature (one course); University Seminar (one course); History (one course); Social Science (one course); Fine Arts or Literature (one course); Philosophy (two courses); Theology (two courses). The University Seminar may be substituted for one of (whichever is applicable): History, Social Science, Fine Arts or Literature; the first Philosophy; the first Theology.*

***Note: Beginning in the spring semester of the junior year the student chooses to follow option A, the structural engineering track or option B, the environmental engineering track. Each track is defined by the three specialization courses shown. Note, that by choice of electives a student may complete both tracks.*

Civil Engineering Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week and laboratory and/or tutorial hours per week and credits each semester are in parentheses.

200, 300, 400. Civil Engineering Service Projects
(variable credit). Staff
Civil Engineering Service Projects (CESP) is a course that partners teams of students with local community service organizations. Projects involve strong technical content, significant design, and multidisciplinary effort and a strong communication component.

225. Mechanics I
(3-0-3) Kirkner
Prerequisites: MATH 126, PHYS 131, EG 111.
Introduction to systems of forces and couples; vector mechanics. Equilibrium of rigid bodies. Internal forces and moments, trusses and beams, distributed loads and properties or areas. Friction and virtual work. Kinematics and kinetics of particle motion. Systems of particles.

231. Probabilistic and Statistical Methods in Civil Engineering
(3-0-3) Kijeswski-Correa
Prerequisite: MATH 225.
Development of probabilistic and statistical techniques for data interpretation, analysis and modeling with application to design and decision making in Civil Engineering.

242. Methods of Civil Engineering
(3-0-3) Vichit-Vadakan
Prerequisites: MATH 126, PHYS 131, corequisite, CE 225.
A rigorous introduction to the tools used in civil engineering. This will include computer programming, exposure to circuits and sensors, surveying/GPS, and use of commercial software packages. These tools and their use will be introduced through a project-oriented pedagogy and strong hands-on experience.

262. Engineering Geology
(3-0-3) Burns
Prerequisites: MATH 126, PHYS 131, CHEM 121.
A study of physical geology and geologic processes relevant to engineering. Emphasis is on the origin and distribution of natural hazards (earthquakes, volcanoes, floods, winds, mass wasting) as they impact built infrastructure, and chemical and physical processes impacting contaminant transport in water. Distribution of natural hazards is considered in the context of Plate Tectonics theory.

335. Civil Engineering Materials
(3-1-4) Vichit-Vadakan
Prerequisite: AME 238.
A study of mechanical properties of civil engineering materials and how they relate to the atomic, microscopic, and macroscopic structure. Weekly laboratories are used to study materials such as steel, concrete, wood, and bituminous materials.

336. Introduction to Structural Engineering
(3-0-3) Kareem
Prerequisite: AME 238.
Introduction to structural engineering; analysis of statically determinate structures; deflection analysis; analysis of indeterminate structures using classical and matrix methods; introduction to analysis software, structural design concepts and code standards.

341. Computational Methods in Civil Engineering
(3-0-3) Westerink
Prerequisite: MATH 228.
Fundamentals of numerical methods and development of programming techniques to solve problems in civil and environmental engineering. The course requires significant computer use via a scientific program language such as Matlab and / or Fortran. Standard topics in numerical linear algebra, interpolation, discrete differentiation, discrete integration, and approximate solution of ordinary differential equations are treated in a context-based approach. Applications are drawn from hydrology, environmental modeling, geotechnical engineering, modeling of material behavior, and structural analysis.

351. Introduction to Geotechnical Engineering
(3-1-4) Salvati
Prerequisites: MATH 325, AME 238.
The objective of this course is to introduce and familiarize the student with the fundamentals of soil mechanics, including behavior of soils in compression and shear, and the principles of geotechnical engineering through lectures and laboratory experiments.

356. Structural Analysis
(3-0-3) Staff
Prerequisite: CE 336.
The fundamentals of matrix methods of analysis. Application to trusses and rigid frames. Introduction to the use of commercial analysis software. Advanced topics of analysis: plastic analysis introduction to structural dynamics.

369. Introduction to Environmental Engineering
(3-0-3) Talley
Prerequisites: MATH 228, CHEM 122.
An introduction to the fundamental concepts of material balances and reactions occurring in reactors. These concepts bind together topics in water supply, wastewater treatment, air pollution control, and management of solid and hazardous wastes. The course describes how a holistic approach, not a fragmented single-pollutant or single-medium, is required to solve environmental problems. Decisions made by environmental engineers require a consideration of environmental ethics, a unifying topic of this course.

410. Air Pollution Engineering
(3-0-3) Woertz
Course will draw upon previous course work in chemistry, mathematics, fluids, thermodynamics and environmental engineering. Types, sources and effects of air pollutants will be covered as well as design of existing technologies used to control emissions. Also, the effect of meteorology on air quality and pollution transport will be discussed.

430. Environmental Chemistry
(3-0-3) Maurice
Prerequisite: Consent of instructor.
Application of acid-base, solubility, complex formation and oxidation reduction equilibria to water supply, wastewater treatment and natural environmental systems.

440. Transportation Engineering
(3-0-3) Staff
Prerequisite: Senior standing in engineering.
The planning, design, operation, safety and economics of transportation systems.

443. Wastewater System Design
(3-1-4) Ketchum
Prerequisite: CE 344.
A study of the theory, design, and operation of facilities both for industrial and municipal treatment and disposal. Design of municipal wastewater treatment systems is emphasized. A significant project/design component is included with a tutorial section.

446. Hydraulics
(3-0-3) Staff
Prerequisites: AME 334.
Theory, analysis, and design of pipe flow, sewer flow, open channel flow, and reservoirs and pumping facilities for water distribution and wastewater collection. Student team design of water distribution and sewer collection systems is emphasized.

444. Groundwater Hydrology
(3-3-4) Silliman
Prerequisite: Senior standing in engineering.
Lectures and laboratory cover the fundamentals of flow and transport in porous media. Methods of analysis for development of groundwater resources.

461. Structural Systems
(3-0-3) Kijewski-Correa
Overview of common structural systems used in design, with specific focus on the hierarchy of lateral load resisting systems. Course will also highlight innovative structural systems of high-rise buildings, collapse mechanisms, and concepts of serviceability and habitability. Codes and commercial software common to practice will be heavily utilized.

465. Foundations and Earth Structures
(3-0-3) Staff
Prerequisite: CE 351.
Application of basic engineering principles of soil mechanics in the design of foundations and earth structures, including deep excavation supports, shallow foundations, deep foundations and cofferdams. Spring.

466. Structural Steel Design
(3-0-3) Kijewski-Correa
Prerequisite: CE 356.
Design of structural steel members / systems using basic fundamentals of mechanics, principles of steel behavior at element and system level. Course integrates current codes/standards and commercial software into semester-long project, providing for direct application of concepts to the design of a mid-rise steel residential/commercial building.

470. Construction Management
(3-0-3) Staff
Prerequisite: Senior standing in engineering.
Engineering aspects of planning, economics, practices, and equipment usage in construction of civil engineering projects. Use of critical path construction schedules. Spring.

473. Environmental/Engineering Design
(3-0-3) Ketchum
Prerequisite: Consent of instructor.
Application of physical, chemical, and biological unit operations and processes to the functional designs of municipal water pollution controls facilities.

474. Environmental Microbiology
(3-0-3) Woertz
Fundamentals of microbiology applied to environmental systems and treatment processes. Emphasis will be placed on kinetics and energetics of microorganisms, fate of environmental pollutants, biotechnology applications, and laboratory techniques used to cultivate organisms and analyze biological systems.

476. Design of Structures to Resist Natural Hazards
(3-0-3) Kareem
Prerequisite: Consent of instructor.
Natural hazards and associated load effects on structures. Analysis of damage caused by wind storms, earthquakes and ocean waves. Design provisions to resist damage resulting from natural hazards.

486. Reinforced Concrete Design
(3-1-4) Kurama
Prerequisite: CE 336.
Mechanics and behavior of reinforced concrete members and structures. Design of reinforced concrete members and structures, including continuous beams, slabs, columns, and frames. Strength and serviceability considerations for design. Building Codes and specifications for reinforced concrete design. Includes a semester-long project on the design of a five-story five-bay reinforced concrete frame building.

Clive R. Neal, associate professor of civil engineering and geological sciences

498. Special Studies
(V-V-V) Staff
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

499. Undergraduate Research
(V-V-V) Staff
A research project at the undergraduate level under the supervision of a faculty member.

The following graduate courses, described in the *Graduate School Bulletin of Information,* are also open to advanced undergraduates with permission of the department chair.

525. Advanced Geostatistics
532. Environmental Biotechnology
534. Design of Biological Waste Treatment Systems
537. Environmental Engineering Principles
539. Advanced Hydraulics
551. Fracture of Materials
563. Finite Elements in Engineering
564. Design of Timber Structures
569. Advanced Structural Dynamics
570. Behavior and Design of Earthquake-Resistant Structures
473/573. Environmental Engineering Design
581. Experimental Methods in Structural Dynamics

* Courses having a 400/500 option will require additional work at the 500 level, i.e., semester project or paper.

Program in Environmental Geosciences. The Environmental Geosciences program at Notre Dame was founded by the Department of Civil Engineering and Geological Sciences to provide students with a quantitative preparation for professional careers or continued higher education in the disciplines of geological and environmental science. The program provides a foundation in the physical sciences, with emphasis on processes that occur near or at the surface of Earth, and the impact of human activity on such processes. Students explore the geochemical, mineralogical, and hydrological properties of Earth's crust and develop an understanding of the interplay of natural processes such as mineral-rock-water-bacteria interactions, with anthropogenic issues such as transport of toxic heavy metals and safe disposal of nuclear waste.

The environmental geosciences program combines classroom, laboratory, and field studies. Students are encouraged to participate in a semester study abroad, such as the Australia program (during the fall semester, junior year), which provides additional opportunity for field-based studies. All students are encouraged to conduct independent research under faculty supervision during their senior year.

An undergraduate major in environmental geosciences prepares a student for graduate study (M.S., Ph.D.) in many aspects of geological and environmental sciences, as well as for admission to a variety of professional schools. In addition, this program meets the criteria for graduates to become sate-registered geologists in states requiring such certification. Graduates with a B.S. degree may enter careers in a wide variety of areas, including the National Park Service, industry, environmental consulting, and government research laboratories. An environmental geosciences degree also is an ideal background for those planning to teach in secondary schools at all levels. Further details can be found at www.nd.edu/~envgeo.

The flexibility of our undergraduate program allows engineering and science students to major in environmental geosciences. Below you will find an example of the curriculum that can be followed by a student who commits to the College of Engineering. This is followed by an example of how a student committed to the College of Science also may take advantage of this major.

First Year of Studies

First-year students intending to major in environmental geoscience when they become sophomores will find first-year requirements on the first page of the College of Engineering section.

Sophomore Year

First Semester

ENVG 231. Physical Geology + Lab	4
ENVG 242. Mineralogy	4
PHYS 132. Physics II	4
MATH 225. Calculus III	3.5
	15.5

Second Semester

ENVG 232. Historical Geology	4
ENVG 247. Petrology	4
MATH 228. Linear Alg. Diff. Equations	3.5
Arts and Letters course[3]	3
Field Trip	1
	15.5

Junior Year

First Semester

ENVG 357. Sediment and Stratigraphy	4
ENVG 403. Geochemistry	3
Arts and Letters course[3]	3
Free elective	3
Technical elective[2]	3
	16

Second Semester

ENVG 342. Str. Geology and Rock Mech.	4
ENVG 344. Surficial Proc. Surf. Hydrol.	3
MATH 214. Introductory Statistics	3
Arts and Letters course[3]	3
Field Trip	1
	14

Senior Year

First Semester

ENVG 415. Env. Imp. Res. Utilization	3
ENVG 423. Environmental Geochemistry	3
CE 444. Groundwater Hydrology	4
Arts and Letters course[3]	3
Arts and Letters course[3]	3
	16

Second Semester

ENVG 462. Environmental Mineralogy	3
ENVG 474. Water-Rock Interaction	3
ENVG 486. Geomicrobiology	3
Technical elective[2]	3
Technical elective[2]	3
	15

Total for the four years: 126 semester hours.

For students in the College of Science wishing to major in the environmental geosciences, the curriculum is very similar, with the following differences, which are underlined:

First Year of Studies

First Semester

ENVG 131. Physical Geology + Lab	4
CHEM 117. General Chemistry I1	4
MATH 125. Calculus I5	4
Arts and Letters course3	3
FYC 1103	3
Physical Education	0
	18

Second Semester

ENVG 112. Environmental Geosciences	3
CHEM 116. General Chemistry II1	4
MATH 126. Calculus II	4
PHYS 131. Physics I	4
Arts and Letters Course	3
Physical Education	0
	17

Sophomore Year

First Semester

Arts and Letters Course3	3
ENVG 242. Mineralogy	4
PHYS 132. Physics II	4
MATH 225. Calculus III	3.5
	14.5

From the spring semester of the sophomore year, the curriculum is the same as that listed above for students in the College of Engineering, except a technical elective is taken in place of an Arts and Letters course during the fall semester of the senior year. The total number of semester credit hours is the same.

MINOR IN ENVIRONMENTAL GEOSCIENCES[4]

A minor in Environmental Geosciences requires the completion of 23 credit hours in geological sciences as follows:

ENVG 131. Physical Geology + lab	4
ENVG 232. Historical Geology	4
ENVG 242. Mineralogy	4
Field Trip	1
Subtotal:	13
One of:	
ENVG 247. Petrology	4
ENVG 342. Str. Geology and Rock Mech.	4
ENVG 357. Sediment. and Stratigraphy	4
Subtotal:	4
Two of:	
ENVG 344. Surficial Proc. Surf. Hydrol.	3
ENVG 403. Geochemistry	3
ENVG 415. Env. Imp. Res. Utilization	3
ENVG 423. Environmental Geochemistry	3
ENVG 459. Paleontology	3
ENVG 462. Environmental Mineralogy	3
ENVG 474. Water-Rock Interaction	3
ENVG 486. Geomicrobiology	3
Subtotal:	6

Total for the minor: 23 semester hours.

Notes:

1. CHEM 113, 115, OR 125 may be substituted for CHEM 117; CHEM 118 or 126 may be substituted for CHEM 116.
2. Technical electives are typically 300- and 400-level courses in science or engineering that have been approved by the chair of Civil Engineering and Geological Sciences. Students must ensure they have met prerequisite requirements for technical elective courses. Courses that may be used as technical electives include:

ENVG 458.	Geophysics
ENVG 459.	Paleontology
ENVG 499.	Undergraduate Research
CHEM 223.	Elem. Organic Chem. I
CHEM 224.	Elem. Organic Chem. II
CHEM 235.	Organic Chemistry + Lab
CHEM 236.	Organic Chemistry + Lab
CHEM 243.	Inorganic Chemistry
CHEM 321.	Physical Chemistry
CHEM 322.	Physical Chemistry II
CHEM 333.	Analytical Chemistry + Lab
CHEM 341.	Fundamentals of Biochemistry
CHEM 420.	Principles of Biochemistry
BIOS 155.	Biological Sciences I
BIOS 156.	Biological Sciences II
BIOS 201.	General Biology I
BIOS 202.	General Biology II
BIOS 401.	Principles of Microbiology
AME 225.	Mechanics I
AME 226.	Mechanics II
AME 330.	Fluid Mechanics
CE 344.	Hydraulics
CE 452.	Int. Water Chem. and Treatment
CE 443.	Wastewater Disposal
MATH 325.	Differential Equations

3. University requirements include:

FYC 110	
*Theology	6 hours
*Philosophy	6 hours
*History	3 hours
*Social Science	3 hours
*Fine Arts or Literature	3 hours

*One of these courses must be a University Seminar 180.

4. If Physical Geology is a required course for a science major, it may also be counted for the minor in Environmental Geosciences.
5. The sequence MATH 165–166 is an acceptable substitute for MATH 125–126. Under special circumstances, MATH 119 may be an acceptable substitute for MATH 125.

Environmental Geosciences Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory hours per week and credits each semester are in parentheses. The instructor's name is also included.

112. Environmental Geosciences
(3-0-3) Fein
Prerequisite: CHEM 117 or equivalent.
This course introduces the student to Earth processes and focuses on how these processes affect people, and how people affect these processes. The course explores the interactions between Earth's biosphere, geosphere, atmosphere, and hydrosphere, with the objective of demonstrating how our physical environment is controlled by geological, biological, and human forces.

131. Physical Geology
(3-2-4) Neal
Open to engineering and science common core intents.
An introduction to the Earth and its processes, composition, evolution, and structure. The course introduces the student to mineralogy, petrology, structural geology, oceanography, surficial processes, geophysics, environmental geology, and planetology. Lecture and laboratory meetings.

231. Physical Geology
(3-2-4) Neal
Open to engineering and science common core intents.
An introduction to the Earth and its processes, composition, evolution, and structure. The course introduces the student to mineralogy, petrology, structural geology, oceanography, surficial processes and environmental geology. Lecture and laboratory meetings.

SUMMARY OF REQUIREMENTS FOR GRADUATION FOR ENVIRONMENTAL GEOSCIENCES MAJOR

	*Credits**
Environmental Geosciences	47 (50)
Chemistry	7
Mathematics	18
Physics	8
Civil Engineering	10 (4)
Technical Electives (science and engineering)	9 (12)
FYC 110	3
Philosophy	6
Theology	6
History	3
Social Science	3
Fine Arts or Literature	3
Free Electives	3
TOTAL CREDITS	126

* *Credits in parentheses refer to students following the College of Science sequence.*

232. Historical Geology
(3-2-4) Rigby
Prerequisite: ENVG 231 or consent of instructor.
This course introduces the student to the concept of geologic time, absolute and relative age-dating, Earth processes and features through time, and the major features of evolution and distribution of fossils. Lecture and laboratory meetings. A one-day field trip is required.

242. Mineralogy and Optical Mineralogy
(3-2-4) Burns
Prerequisite: CHEM 118, ENVG 231, or consent of instructor.
Crystallography and mineral optics: physical and chemical mineralogy—its application to mineral identification in hand-specimen and using the petrographic microscope.

247. Igneous and Metamorphic Petrology
(3-2-4) Neal
Prerequisite: ENVG 242 or consent of instructor.
Origin and identification of igneous and metamorphic rocks within a plate tectonic framework. Geochemistry and petrography are used to investigate mineral equilibria, magma generation and crystallization, pressure and temperatures of deformation, and the interior of the Earth.

342. Structural Geology and Rock Mechanics
(3-3-4) Staff
Prerequisite: ENVG 242 or consent of instructor.
Shapes and fabric of deformed rocks, physical properties of rocks, processes and mechanisms of deformation with associated stresses and strains, and regional and global structural events. A weekend field trip is required.

344. Surficial Processes and Surficial Hydrology
(2-3-3) Staff
Prerequisite: ENVG 242 or consent of instructor.
A quantitative study of natural chemical and physical processes (e.g., weathering, flooding, wind) that produce both erosional and depositional landforms. Their effects on human structures and developments are explored. A one-day field trip is required.

357. Sedimentation and Stratigraphy
(3-2-4) Rigby
Prerequisite: ENVG 242 or consent of instructor.
Sedimentary environments from a physical, biological and tectonic perspective are explored, along with processes such as lithification. Identification of sedimentary rocks and the interpretation of the succession of layered rocks in North America are emphasized.

403/503. Geochemistry
(3-0-3) Fein
Prerequisites: CHEM 116, 117; MATH 125, 126, or consent of instructor.
An introduction to the use of chemical thermodynamics and chemical kinetics in modeling geochemical processes. Special emphasis is placed on water-rock interactions of environmental interest.

415. Environmental Impact of Resource Utilization
(3-0-3) Neal
Prerequisite: ENVG 242, ENVG 403, or consent of instructor.
The environmental effects of utilizing natural resources are examined from their extraction, refining, to use. Pivotal in this course is environmental impact assessment and rehabilitation/remediation technologies. A number of case studies will be examined to highlight the environmental impact of using the Earth's natural resources and how such impacts can be mitigated.

423. Environmental Geochemistry
(3-0-3) Maurice
Prerequisite: ENVG 403 or consent of instructor.
The fundamental controls on the chemical characteristics of natural waters as a basis for understanding local, regional, and global hydrobiochemical cycles. Includes acid-base equilibria, solubility, complex formation, geochemistry of clays, and introduction to geochemical kinetics. Combines classical geochemical, engineering, and computer modeling approaches to carbonate system equilibria.

445. Field Trip
(0-2-1) Burns
Prerequisite: ENVG 231 or consent of instructor.
Field trip during the fall/spring vacation; emphasis on regional field geology and field relationships. Classic localities are studied in order to demonstrate geological concepts.

458. Geophysics
(2-2-3) Staff
Prerequisite: MATH 228, PHYS 132, or consent of instructor.
Physics of the solid Earth: seismic wave, gravity, resistivity and electromagnetic methods of probing the structure of the Earth. Applications to environmental concerns as well as to groundwater, mineral and petroleum exploration are discussed.

459. Paleontology
(2-2-3) Rigby
Prerequisite: ENVG 232 or consent of instructor.
The fossil record—morphology, taxonomy, evolution, statistical population systematics and paleoecology. A one-day field trip is required.

462. Environmental Mineralogy
(3-0-3) Burns
Prerequisite: ENVG 242 or consent of instructor.
This course explores the chemistry and structures of minerals with emphasis on environmental and technological issues. Topics of environmental significance include disposal of spent nuclear fuel, contamination of soils with heavy metals, and the remediation of mine tailings. Emphasis will be on the mineralogy of uranium, lead, mercury, iodine, selenium, and tellurium. Technological aspects of minerals, such as the use of zeolites and clay minerals as molecular sieves and as waste containment vessels, will be addressed.

474. Water-Rock Interactions
(3-0-3) Maurice
Prerequisite: ENVG 423 or consent of instructor.
Fundamental properties of mineral surfaces and of the mineral-water interface. Methods of surface and interface analysis. The electric double layer. Interface reactions including adsorption, mineral growth and dissolution, photoredox phenomena, and controls on bacterial adhesion.

486. Geomicrobiology
(3-0-3) Fein
Prerequisite: ENVG 403 or consent of instructor.
This course explores current research involving the interaction between microbes and geologic systems, focusing on the ability of microbes to affect mass transport in fluid-rock systems. Readings concentrate on laboratory, field, and modeling studies of environmental and/or geologic interest.

497. Directed Readings
(0-V-V) Staff
Prerequisite: Permission of the chair of the Department of Civil Engineering and Geological Sciences and the individual instructor.
Research of literature on a specific geoscience topic. Preparation of reports and presentations.

498. Special Studies
(V-V-V) Staff
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

499. Undergraduate Research
(0-V-V) Staff
Prerequisite: Permission of the chair of the Department of Civil Engineering and Geological Sciences.
Three to 15 hours each week, arranged individually for each student.

The following graduate courses, described in the *Graduate School Bulletin of Information,* are also open to advanced undergraduates with permission:
403/503. Geochemistry
519. Surface and Subsurface Geophysics
528. ICP Analytical Techniques
545. Biogeochemical Cycles
547. Geodynamics
568. Environmental Isotope Geochemistry

Computer Science and Engineering

Schubmehl/Prein Chair of Computer Science and Engineering:
Kevin W. Bowyer
Ted H. McCourtney Professor of Computer Science and Engineering:
Peter M. Kogge
Professors:
Steven C. Bass (emeritus); Danny Z. Chen; Patrick Flynn; Eugene W. Henry (emeritus); John J. Uhran Jr.
Associate Professors:
Jay B. Brockman; X. Sharon Hu
Assistant Professors:
Surendar Chandra; Jesús A. Izaguirre; Maria Michael (visiting); Lambert Schaelicke; Matthias Scheutz; Aaron Striegel
Professional Specialist:
Gregory R. Madey
Associate Professional Specialist:
Ramzi K. Bualuan; J. Curt Freeland

Program of Studies. The Department of Computer Science and Engineering offers programs of study which lead to the degrees of bachelor of science in computer science and bachelor of science in computer engineering. The program in computer engineering is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The department also offers programs that lead to a master of science in computer science and engineering, and a Ph.D.

Educational Goals. The goals of the programs in computer science and computer engineering are (1) to prepare all students for careers in the public or private sector, (2) to prepare outstanding students for graduate study, (3) to develop life-long learning skills in all students, (4) to provide comprehensive education in computer science, including theoretical foundations, software and hardware systems, and applications, and (5) to ensure significant design experience including working in teams.

Program Outcomes. At the time of completion of the undergraduate program, all graduates should possess (1) the ability to specify, design, test, and document software, (2) an understanding of current computer software and hardware technology, (3) an understanding of science, engineering, and mathematics, (4) a comprehensive general education, (5) the ability to continue learning in response to professional needs as well as personal desire for self-improvement, and (6) an understanding of personal and professional responsibility to society.

Programs. Programs in the Department of Computer Science and Engineering follow the four-year curricula listed below. These include required and elective courses in the basic, pure and applied sciences, as well as the humanities, electrical engineering, computer science and computer engineering. Emphasis is on developing a mastery of the key principles underlying the organization, operation, and application of modern computers to real problems, with a solid grounding in math and science to permit a quantative analysis of such solutions. In addition, central to both programs is the development of the ability to function, both independently and in multidisciplinary teams, and to be prepared for continued change in future computing technology and what effects it will have on all aspects of society. Opportunities for specialization in several professional computer disciplines are available. Students are individually assisted and advised in their choices of elective courses.

Department facilities include a laboratory to support instruction in System Administration and Network Management courses, and research facilities in distributive computing and computational techniques which are used by undergraduates as well. Moreover, the department uses UNIX workstations, which support modern computer-aided design tools for the design of computer systems and integrated circuits (VLSI) in many courses. Also available is a laboratory for the fabrication of integrated circuits designed by students in the "bits-to-chips" program.

Further information about computer science and computer engineering programs may be found on the World Wide Web at www.cse.nd.edu.

PROGRAM IN COMPUTER SCIENCE

The Program in Computer Science focuses on the application of computers to real problems, especially in the design, development, and use of software. The program is designed to foster an understanding of the key properties of algorithms (the mathematical statements of how problems are to be solved), and how to recognize and design good algorithms to solve real problems in efficient fashions. The program also includes developing the ability to engineer large, efficient, portable, and scalable pieces of software that implement good algorithms in ways that are useful to the end users, and to do so in ways that use modern software development tools and techniques.

PROGRAM IN COMPUTER ENGINEERING

The Program in Computer Engineering focuses on understanding the basic nature of the electronic devices that go into the creation of modern computers and on the detailed architecture and organization of such systems, both within the Central Processing Unit and in how larger systems are assembled. Modern design tools and techniques are introduced very early in the program and used throughout to design, analyze, and prototype real digital computing systems. All computer engineering students are required to enroll in at least one of a prescribed set of design courses before graduation.

FIRST YEAR OF STUDIES

First-year students intending to major in computer engineering or in computer science when they become sophomores will find first-year course requirements on the first page of the College of Engineering section.

COMPUTER ENGINEERING PROGRAM:

Sophomore Year
First Semester

CSE 211. Fundamentals of Computing I	4
CSE 210. Discrete Mathematics	3
MATH 225. Calculus III	3.5
PHYS 132. General Physics II	4
Arts and Letters course+	3
	17.5

Second Semester

CSE 212. Fundamentals of Computing II	4
CSE 221. Logic Design	4
MATH 228. Introduction to Linear Algebra and Differential Equations	3.5
Technical Elective	3
Arts and Letters course+	3
	17.5

Junior Year
First Semester

CSE 331. Data Structures	3
CSE 321. Computer Architecture I	4
EE 224. Introduction to Electrical Engineering	4
Free Elective	3
Arts and Letters course+	3
	17

Second Semester

CSE 322. Computer Architecture II	4
CSE 341. Operating System Principles	3
EE 234. Electric Circuits	3
MATH 323. Probability	3
Arts and Letters course+	3
	16

Senior Year
First Semester

EE 344. Signals and Systems I	3
CSE Electives*	9
Free Elective	3
	15

Second Semester

CSE 475. Ethics and Professional Issues	3
EE 242. Electronics I	4
CSE Elective*	3
Arts and Letters course+	3
	13

Total Program Credits: 130

COMPUTER SCIENCE PROGRAM:

Sophomore Year
First Semester

CSE 211. Fundamentals of Computing I	4
CSE 210. Discrete Mathematics	3
MATH 225. Calculus III	3.5
PHYS 132. General Physics II	4
Arts and Letters course+	3
	17.5

Second Semester

CSE 212. Fundamentals of Computing II	4
CSE 221. Logic Design	4
MATH 228. Introduction to Linear Algebra and Differential Equations	3.5
Technical Elective	3
Arts and Letters course+	3
	17.5

Junior Year
First Semester

CSE 331. Data Structures	3
CSE 321. Computer Architecture I	4
CSE Elective*	3
Technical Elective	3
Arts and Letters course+	3
	16

Second Semester

CSE 351. Theory of Computing	3
CSE 341. Operating System Principles	3
CSE Elective*	3
MATH 323. Probability	3
Arts and Letters course+	3
	15

Senior Year
First Semester

CSE 413. Algorithms	3
CSE Electives*	6
Technical Elective	3
Free Elective	3
	15

Second Semester

CSE 475. Ethics and Professional Issues	3
CSE Electives*	6
Arts and Letters course+	3
	12

Total Program Credits: 127

+ See "Arts and Letters Core" on the first page of the College of Engineering section.
** These courses must be selected from a list approved by the department. For computer engineering, at least one must be a designated design course.*

Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week, and credits each semester are in parentheses.

210. Discrete Mathematics
(3-0-3) Madey
Introduction to mathematical techniques fundamental to computer engineering and computer science. Topics: mathematical logic, induction, set theory, relations, functions, recursion, recurrence relations, introduction to asymptotic analysis, algebraic structures, graphs, machine computation.

211. Fundamentals of Computing I
(3-1-4) Scheutz
Prerequisites: EG 112.
This is the first part of a two-course introduction-to-computing sequence, intended primarily for computer science and computer engineering majors. It introduces fundamental concepts and principles of computer science, from formulating a problem and analyzing it conceptually, to designing, implementing, and testing a program on a computer. Using data and procedural abstractions as basic design principles for programs, students learn to define basic data structures, such as lists and trees, and to apply various algorithms for operating on them. The course also introduces object-oriented and parallel programming methods. The primary programming language used in this course is SCHEME.

212. Fundamentals of Computing II
(3-1-4) Izaguirre
Prerequisite: CSE 211.
This is the second part of a two-course introduction-to-computing sequence, intended primarily for Computer Science and Computer Engineering majors. This course introduces concepts and techniques for developing large software systems. The object-oriented model of design and programming is presented using a modern programming language such as Java or C++. Topics covered include modularity, specification, data abstraction, classes and objects, genericity, inheritance, subtyping, design patterns, testing, concurrency, object persistency, and databases.

221. Logic Design and Sequential Circuits
(3-3-4) Michael, Flynn
Boolean algebra and switching circuits, Karnaugh maps, design of combinational and of sequential logic networks, sequential machines.

232. Advanced Programming
(3-0-3) Bualuan
Prerequisite: MATH 125.
Top-down analysis and structured programming. Basic analysis of algorithms, algorithm development, implementation and debugging and testing of programs will also be emphasized. Students will write several programs in the C++ language to learn the concepts taught and to acquire experience in solving problems using the UNIX operating system.

Matthias Scheutz, assistant professor of computer science and engineering

321. Computer Architecture I
(3-3-4) Hu
Prerequisites: CSE 221, CSE 212.
Introduction to basic architectural concepts that are present in current scalar machines, together with an introduction to assembly language programming, computer arithmetic and performance evaluation. Commercial computer-aided-design software is used to deepen the student's understanding of the top-down processor design methodology. MIPS-based assembly language will be used.

322. Computer Architecture II
(3-3-4) Kogge
Prerequisite: CSE 321.
A continuation of the architectural concepts in CSE 321. Detailed study of processor design, hardwired and microprogrammed control, pipelining, memory organization, I/O and bus protocols, parallel processors. The course makes extensive use of commercial computer-aided-design tools and culminates with a major project of designing and simulating a complete microprocessor.

331. Data Structures
(3-0-3) Izaguirre
Prerequisite: CSE 210, CSE 212.
Fundamental techniques in the design and analysis of non-numerical algorithms and their data structures. Elementary data structures such as lists, stacks, queues; more advanced ones such as priority queues and search trees. Design techniques such as divide-and-conquer. Sorting and searching and graph algorithms.

341. Operating System Principles
(3-0-3) Madey, Schaelicke
Corequisite: CSE 321.
Introduction to all aspects of modern operating systems. Topics include process structure and synchronization, interprocess communication, memory management, file systems, security, I/O and distributed files systems.

346. Database Concepts
(3-0-3) Bualuan
Effective techniques in managing, retrieving and updating information from a database system. Focusing primarily on relational databases, the course presents the entity-relationship model, query processing and normalization. Topics such as relational calculus and algebra, integrity constraints, distributed databases and data security will also be discussed. A final project will consist of the design and implementation of a database system.

351. Theory of Computing
(3-0-3) Karavelas
Prerequisite: CSE 331.
The theory of automata and formal languages is developed along with applications. Various classes of automata, formal languages, and the relations between these classes are studied. Restricted models of computation; finite automata and pushdown automata; grammars and their relations to automata; parsing; turing machines; limits of computation: undecidable problems, the classes of P and NP.

413. Algorithms
(3-0-3) Chen
Prerequisite: CSE 331.
Techniques for designing efficient computer algorithms and for analyzing computational costs of algorithms. Common design strategies such as dynamic programming, divide-and-conquer, and Greedy methods. Problem-solving approaches such as sorting, searching and selection; lower bounds; data structures; algorithms for graph problems; geometric problems; and other selected problems. Computationally intractable problems (NP-completeness). Parallel algorithms.

422. Computer System Design
(3-0-3) Hu
Prerequisite: CSE 322.
Integrated hardware and software development, construction and test of digital systems by design teams to meet specifications subject to technical, economic and environmental constraints.

431. Programming Languages
(3-0-3) Kogge
Prerequisite: Familiarity with a standard programming language.
An introduction to modern computing concepts and computational models as embodied in a number of different classes of languages. These include (1) functional-based languages such as Lisp, Scheme, SASL, ML; (2) logic-based languages such as Prolog, Parlog, Strand, OPS; and (3) object-oriented languages such as Smalltalk, C++, Java.

432. Software Engineering
(3-0-3) Schaelicke
Prerequisites: CSE 331, CSE 341.
A comprehensive course about the methodologies required to control the complexity involved in the development of large software systems. Students are given the opportunity to practically apply software engineering techniques taught in this course through several medium-size programming problems and one large-scale development project. Emphasis is on the use of requirements and prototyping for design and software reliability, reuse, and development management.

443. Compilers
(3-0-3) Staff
An introduction to the fundamental techniques and tools used in compiler construction. Topics include high-level language specification via context-free grammars; lexical analysis; parsing techniques such as top-down, bottom-up, and LR parsing; run-time environments; and code generation.

444. Introduction to Systems Administration
(3-0-3) Freeland
An introduction to the concepts and practices of computer system administration, including software management, system device management, system security, management of system services, disaster planning and disaster recovery.

456. Data Networks
(3-0-3) Staff
Prerequisite: Fundamental probability theory.
Introduction of fundamental concepts of data networks in terms of the ISO-layered architecture. Functions that occur at the various levels are explored. Topics include local area networks such as Ethernet and Token Ring networks, proposals for wide and metropolitan area networks such as FDDI and DQDB, and the eventual integration of data communications into a single network under ISDN (Integrated Services Digital Network) and Broadband ISDN.

458. Network Management
(3-0-3) Freeland
An introduction to the concepts and practices of computer network management, including network installation, monitoring and troubleshooting.

462. VLSI Circuit Design
(3-0-3) Brockman
Prerequisite: CSE 221.
CMOS devices and circuits, scaling and design rules, floor planning, data and control flow, synchronization and timing. Individual design projects.

466. Computer Graphics
(3-0-3) Flynn
Prerequisites: Linear algebra, high-level language.
Graphics Display devices. Two- and three-dimensional geometry: transformations and projections. Raster graphics algorithms; primitive rendering; 3-D modeling; scene description. Graphics software standards. Software projects.

471. Introduction to Artificial Intelligence
(3-0-3) Scheutz, Flynn
Prerequisite: Advanced standing in engineering or science.
Evaluation of the areas that make up artificial intelligence today. Development of various representations commonly used. Differences between knowledge bases and databases are explored. A study of several applications including expert systems.

472. Introduction to Neural Networks
(3-0-3) Scheutz
Prerequisite: Advanced standing in engineering or science.
A study of the origin of artificial networks and their relationship to the biological world. An evaluation of four basic network structures: their properties, mathematical descriptions and applications.

475. Ethical and Professional Issues
(3-0-3) Bowyer
This course seeks to develop a solid foundation for reasoning about the difficult ethical, professional, and social controversies that arise in the computing field. Emphasis is placed on identifying the appropriate legal and professional context and applying sound critical thinking skills to a problem. Topics covered include relevant professional codes of ethics, encryption/privacy/surveillance, freedom of speech, "cracking" of computer systems, development of safety-critical software, whistleblowing, and intellectual property. This course relies heavily on case study of real incidents, both historical and current.

498. Special Studies
(V-V-V) Staff
Individual or small group study under the direction of a CSE faculty member in an undergraduate subject not currently covered by any University course.

499. Undergraduate Research
(V-V-V) Staff
A research project at the undergraduate level under the supervision of a CSE faculty member.

Electrical Engineering

Chair:
Yih-Fang Huang
H.C. and E.A. Brosey Professor of Electrical Engineering:
Panagiotis J. Antsaklis
Leonard Bettex Chair of Electrical Engineering in Communications:
Daniel J. Costello Jr.
Frank M. Freimann Professor of Electrical Engineering:
Craig Lent
Frank M. Freimann Professor of Electrical Engineering (emeritus):
Ruey-wen Liu
Frank M. Freimann Professor of Electrical Engineering:
James L. Merz
Frank M. Freimann Professor of Engineering (emeritus):
Anthony N. Michel
Frank M. Friemann Professor of Electrical Engineering:
Wolfgang Porod
Frank M. Freimann Professor of Electrical Engineering:
Michael K. Sain
Professors:
Peter H. Bauer; Gary H. Bernstein; William B. Berry (emeritus); Oliver M. Collins; Thomas E. Fuja; Eugene W. Henry (emeritus); Yih-Fang Huang; Joseph C. Hogan (emeritus); Michael D. Lemmon; Alan C. Seabaugh; Robert L. Stevenson; John J. Uhran Jr.
Associate Professors:
Patrick J. Fay; Garabet J. Gabriel (emeritus); Douglas C. Hall; Thomas H. Kosel; Ken D. Sauer; Gregory L. Snider
Assistant Professors:
Martin Haenggi; Debdeep Jena; John B. Kenney (adjunct); J. Nicholas Laneman; Paulo Tabuada; Huili (Grace) Xing
Research Associate Professor:
Alexander Mintairov; Alexei Orlov
Professional Specialist:
R. Michael Schafer
Assistant Professional Specialist:
John Ott
Concurrent Faculty:
Kevin Bowyer; Jay Brockman; Patrick Flynn; Sharon Hu; Joachim Rosenthal

Statement of Goal and Objectives. The goal of the Department of Electrical Engineering's academic programs is to provide quality education and foster leading-edge research as a means of training highly qualified engineers and leaders of tomorrow, in keeping with the mission of the University of Notre Dame. The educational objectives through which this goal is met are:
• a thorough foundation for each graduate in basic scientific and mathematical knowledge, and in skills appropriate for practice in the field of electrical engineering immediately after graduation and well into the future.
• preparation of electrical engineering students for graduate and professional degree programs.
• breadth in education preparing graduates for adaptation to varied career paths and changing professional landscapes.

Program of Studies. The Department of Electrical Engineering offers programs of study that lead to the degrees of bachelor of science and master of science in electrical engineering and doctor of philosophy. The program leading to the bachelor of science degree is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

Program in Electrical Engineering. The four-year curriculum, listed below, includes required and elective courses in the pure and applied sciences, the humanities and electrical engineering. Emphasis is on the mastery of fundamental principles, with added depth and provision for specialization in the following major professional areas of communications, control systems, electronic circuits, design and analysis, microelectronics and integrated circuits, fabrication, photonics, and signal processing. Students are individually assisted and advised in their choices of elective courses. Departmental facilities include laboratories for electronics, circuits, electrophysics, control systems, communications, integrated circuit fabrication, photonics, and microwave circuit/device characterization. State-of-the-art computers are available for use in all classes.

Further details about the electrical engineering program may be found on the World Wide Web at www.nd.edu/~ee.

First Year of Studies
First-year students intending to major in electrical engineering when they become sophomores will find first-year course requirements on the first page of the College of Engineering section.

Sophomore Year
First Semester

MATH 225: Calculus III	3.5
PHYS 132: General Physics II	4
CSE 232: Advanced Programming	3
EE 224: Introduction to Electrical Engineering	4
Arts and Letters course+	3
	17.5

Second Semester

MATH 228: Introduction to Linear Algebra and Differential Equations	3.5
PHYS 231: General Physics III	3.5
EE 242: Electronics I	4
EE 234: Electric Circuits	3
CSE 221: Logic Design	4
	18

Junior Year
First Semester

MATH 325: Differential Equations	3
EE 344: Signals and Systems I	3
EE 347: Semiconductors I	3
EE 348: Electromagnetic Fields and Waves I	3
Arts and Letters course+	3
	15

Second Semester

MATH 323: Probability	3
Electrical Engineering Electives*	6
Technical Elective	3
Arts and Letters course+	3
	15

Senior Year
First Semester

EE 430: Senior Design I	3
Electrical Engineering Electives*	6
Engineering Science Elective†	3
Arts and Letters course+	3
	15

Second Semester

EE 440: Senior Design II	3
Electrical Engineering Electives*	6
Technical Elective#	3
Arts and Letters course+	3
	15

Total for four years: 129.5 semester hours.

** At least one electrical engineering elective must be chosen from EE 342, 446, 455, 458, and 468.*

+ See "Arts and Letters Core" on the first page of the College of Engineering section.

† The engineering science elective must be chosen from a list of approved courses found on the Electrical Engineering Web site.

 # The technical electives must be chosen from the approved technical elective course list.

Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week and laboratory and/or tutorial hours per week and credits each semester are in parentheses.

224. Introduction to Electrical Engineering
(3-3-4) Lemmon
Corequisites: MATH 225 and PHYS 132.
A project-oriented introduction to electrical engineering principles in which long-term projects are used to introduce such topics as node and loop analysis, network theorems, first-order circuits, operational amplifiers, communication, systems theory, microprocessor interfacing techniques, and computer programming. Fall.

234. Electric Circuits
(3-0-3) Sain
Prerequisite: EE 224.
Corequisite: MATH 228.
Analysis of first, second, and higher order circuits, including natural response, forced response, phasor concepts, AC methods, frequency response, and Laplace transform techniques. Spring

242. Electronics I
(3-3-4) Stevenson
Prerequisite: EE 222 or 224.
Introduction to electronic circuits and systems. Voltage and feedback amplifiers. Logic and analog circuits utilizing discrete solid-state devices. Spring.

342. Electronics II
(3-3-4) Fay
Prerequisite: EE 242.
Fundamentals of transistor integrated circuit design, including frequency response, feedback, stability, and frequency compensation with application to operational amplifiers, phase-locked loops, and AM/FM transmission and reception. Includes laboratory. Spring.

344. Signals and Systems I
(3-0-3) Haenggi
Prerequisites: EE 234, MATH 228.
Behavior of linear systems in both time- and transform-domain representations; convolution integrals and summations, Fourier series signal expansions, Fourier and Laplace transform analysis of linear systems; discrete time Fourier transforms. Fall.

347. Semiconductors I: Fundamentals
(3-0-3) Hall
Prerequisites: PHYS 231, MATH 228.
An introduction to solid-state electronic devices, presenting the basis of semiconductor materials, conduction processes in solids, and other physical phenomena fundamental to the understanding of transistors, optoelectronic devices and silicon integrated circuit technology. Fall.

348. Electromagnetic Fields and Waves I: Fundamentals
(3-0-3) Seabaugh
Prerequisites: EE 234, PHYS 231.
A basic course in electromagnetic field theory, using Maxwell's equations as the central theme. Vector analysis is employed extensively. Fall.

354. Signals and Systems II
(3-0-3) Laneman
Prerequisite: EE 344.
Linear systems analysis with emphasis on discrete time case; sampling theory, discrete Fourier transform, Z-transform, applications in signal processing, communcations and control. Spring.

357. Semiconductors II: Devices
(3-0-3) Porod
Prerequisite: EE 347.
Applications of transport phenomena in semiconductors to explain the terminal behavior of a variety of modern electronic devices such as bipolar junction transistors, MOS structures and field effect transistors. Spring.

358. Electromagnetic Fields and Waves II: Applications
(3-0-3) Lent
Prerequisite: EE 348.
Propagation of traveling waves along transmission lines: transient waves, steady-state sinusoidal time and space variations. Wave equations for unbounded media and in wave guides. Spring.

372. Electric Machinery and Power Systems
(3-0-3) Sauer
Prerequisite: EE 348 or consent of instructor.
Introduction to electric power systems and electromechanical energy conversion, including generators, transformers, three-phase circuits, AC and DC motors, transmission lines, power flow, and fault analysis. Spring.

430. Senior Design I
(1-6-3) Schaefer
The first part of a yearlong senior design project. In this part, students will choose a project, develop the paper design, plan the implementation and purchase necessary materials. Fall.

440. Senior Design II
(0-9-3) Schaefer
The second part of a yearlong senior design project. In this part, students implement, test and document their senior project. Spring.

446. IC Fabrication Laboratory
(2-6-4) Snider
This course introduces the student to the principles of integrated circuit fabrication. Photolithography, impurity deposition and redistribution, metal deposition and definition, and other topics. Students will fabricate a 550 gate (2500 transistor) CMOS LSI circuit. Fall.

453. Communication Systems
(3-0-3) Collins
Prerequisites: MATH 323, EE 354.
An introduction to the generation, transmission and detection of information-bearing signals. Analog and digital modulation techniques including AM, FM, PSK, QAM, and PCM. Time and frequency division multiplexing. Fall.

455. Control Systems
(3-3-4) Antsaklis
Prerequisites: EE 354, MATH 325.
Design of linear feedback control systems by state-variable methods and by classical root locus, Nyquist, Bode and Routh-Hurwitz methods. Fall.

456. Data Networks
(3-0-3) Kenney/Schafer
Prerequisite: Fundamental probability theory.
Introduction of fundamental concepts of data networks in terms of the ISO-layered architecture. Functions that occur at the various levels are explored. Topics include local area networks such as Ethernet and Token Ring networks, proposals for wide and metropolitan-area networks such as FDDI and DQDB, and the eventual integration of data communications into a single network under ISDN (Integrated Digital Services Network) and Broadband ISDN.

458. Microwave Circuit Design and Measurements Laboratory
(2-3-3) Fay
Prerequisites: EE 348 or consent of instructor.
This course is an introduction to microwave circuit design and analysis techniques, with particular emphasis on applications for modern microwave communication and sensing systems. An integrated laboratory experience provides exposure to fundamental measurement techniques for device and circuit characterization at microwave frequencies. Students will develop an enhanced understanding of circuit design and analysis principles as applied to modern microwave circuits, as well as become familiar with design techniques for both hand analysis and computer-aided design. An appreciation for basic measurement techniques for characterization of microwave devices, circuits and systems through laboratory experiments will also be developed. Fall.

462. VLSI Circuit Design
(3-0-3) Brockman
Prerequisites: CSE 221, EE 242.
CMOS devices and circuits, scaling and design rules, floor planning, data and control flow, synchronization and timing. Individual design projects.

464. Introduction to Neural Networks
(3-0-3) Uhran
Prerequisite: Advanced standing in engineering or science.
A study of the origin of artificial networks and their relationship to the biological world. An evaluation of four basic network structures and their properties, mathematical descriptions and applications.

465. Space Systems and Analysis
(3-0-3) Collins
Missions, spacecraft dynamics, attitude determination and control, space environment, spacecraft power, telecommunications, avionics, data handling/processing, and other topics that may include configuration, load determination and structure, and thermal control.

466. Topics in Electronic Transport Theory
(3-0-3) Porod
Prerequisite: EE 357.
Phenomenology: Drude and Sommerfeld theories of conduction. Transport theory: Boltzmann equation, relaxation time approximation, hot electrons, velocity overshoot. Advanced concepts: theory of scattering processes, impurity scattering, deformation potential scattering, Monte Carlo method.

468. Modern Photonics Laboratory
(2-3-3) Hall
A hands-on overview of the important role of photons alongside electrons in modern electrical engineering. Photonics technologies studied include lasers, optical fibers, integrated optics, optical signal processing, holography, optoelectronic devices and optical modulators. A survey of the properties of light, its interactions with matter, and techniques for generating, guiding, modulating, and detecting coherent laser light. Spring.

471. Digital Signal Processing
(3-0-3) Haenggi
Prerequisite: EE 354 and MATH 323.
An introduction to the theory and application of digital information processing: analog/digital and digital/analog conversion, transform domain representation of discrete-time signals and systems, Z-transform, signal flow graphs, discrete Fourier transform, fast Fourier transforms, frequency analysis, filter design, filter structures, Wiener filter, finite-precision effects, applications in communications and the analysis and synthesis of audio and image data. Spring.

476. Electronic Properties of Materials
(3-0-3) Kosel
Prerequisite: EE 347 or equivalent.
Introduction to the electrical properties of materials. Quantum theory. Band theory of solids. Fundamentals of metal and semiconductor properties as related to solid-state devices.

486. Digital and Analog Integrated Circuits
(3-0-3) Snider
Prerequisites: EE 342, EE 357.
Device-level operation of digital and analog integrated circuits. Covers the elements of silicon bipolar and MOS logic, GaAs logic, and volatile and non-volatile memory. Topics in analog ICs include the design of transistors optimized for particular applications such as high bandwidth, AC and DC analysis of analog circuits, and subcircuits used in analog ICs. Design issues.

498. Special Studies
(V-V-V) Staff
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

499. Undergraduate Research
(V-V-V) Staff
A research project at the undergraduate level under the supervision of a faculty member.

Douglas C. Hall, associate professor of electrical engineering

The following graduate courses, described in the Graduate School Bulletin of Information, are also open to advanced undergraduates with permission of the department chair.

550. Linear Systems
551. Mathematical Programming
553. Advanced Digital Communications
554. Computer Communication Networks
555. Multivariable Control Systems
556. Fundamentals of Semiconductor Physics
558. Microwave Circuit Design & Meas.
561. Multi-Dimensional Signal Processing
563. Random Variables and Stochastic Processes
566. Solid State Devices
568. Electromagnetic Theory I
571. Statistical Signal Processing
576. Microelectronic Materials
580. Nonlinear Control Systems
581. Digital Image Processing

Interdepartmental Engineering

COURSE DESCRIPTIONS

The engineering course description is used for courses whose teaching responsibility rests with two or more departments of the College of Engineering. The descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week and credits each semester are in parentheses.

111. Introduction to Engineering Systems I
(3-0-3) Staff
Prerequisite: First-year standing.
The first of a two-part sequence intended to introduce engineering to First Year intents and to establish a foundation for their studies in any of the engineering disciplines. Team-oriented design projects are used to provide a multidisciplinary view of engineering systems and to present the engineering method. Computing skills are developed for engineering analysis, synthesis, and technical communication.

112. Introduction to Engineering Systems II
(3-0-3) Staff
Prerequisite: First-year standing.
The second of a two-course sequence intended to continue the introduction of First Year intents to the engineering disciplines. Projects are used to illustrate the application of engineering modeling, analysis and design principles to solve a variety of practical problems. The projects are intended to span areas of interest in departments of the College of Engineering. Structured programming and computing skills are further developed.

421. Integrated Engineering and Business Fundamentals
(3-0-3) Dunn
Prerequisite: Junior or senior standing.
The course is designed to improve the effectiveness of engineers work in corporations by teaching how and why businesses operate. Subjects covered include business financial reporting, human resource processes, management, the development processes, project management, the supply chain, and a history of quality topics. Numerous guest speakers are utilized to give the students exposure to successful business executives and reinforce the business processes covered in class.

422. Advanced Integrated Engineering and Business Topics
(3-0-3) Dunn
Prerequisite: EG 421.
The second course in the sequence integrates the elements taught in the fundamentals course. Subjects covered include a team-oriented Web-based business simulation exercise, building a successful plan, effective communications, and a review of leading edge trends in modern corporations.

Dual Degree Programs

DUAL DEGREE PROGRAM WITH THE COLLEGE OF ARTS AND LETTERS

Coordinators:
John J. Uhran Jr.
Associate dean
College of Engineering

Ava Preacher
Assistant dean
College of Arts and Letters

Program of Studies. The dual degree five-year program between the College of Arts and Letters and the College of Engineering enables the student to acquire degrees from both colleges—the bachelor of arts from the College of Arts and Letters and the bachelor of science degree in a chosen program of the College of Engineering.

This combination program, instituted in 1952, offers students the advantages of both a liberal and a technical education. The student completing one of these combination programs has a background in the humanities and social sciences as well as a degree from one of the programs offered by the College of Engineering. Because it is a demanding program, only those students who have both the aptitude and motivation necessary for the five-year program, should apply. Advisors for the program are available for consultation about the advisability of entering the program and about meeting the particular needs of each student pursuing this program. Qualified students are eligible to receive modest scholarship support from the John J. Reilly Endowed Scholarship program during their fifth year of study.

The decision to enter the program ordinarily should be made prior to beginning studies in the first year of studies, although students can also enter the program at a later stage. There are three sets of requirements which must be met by the program: University requirements, Arts and Letters requirements and those of the College of Engineering, as the following table indicates.

University Requirements

Philosophy	6
Theology	6
Composition	3
University Seminar+	(3)
History	3
Social Science	3
Literature or Fine Arts	3
Mathematics (MATH 125, 126)	8
Natural Science (CHEM 121, 122)	7
	39

Arts and Letters Requirements

CSEM 210	3
Literature or Fine Arts*	3
History or Social Science	3
Language**	6/9
Major (minimum)	27
	42/45

Engineering Requirements

MATH 225, 228	7
PHYS 131, 132	8
EG 111, 112	6
	21

Engineering Program

Engineering degree program (required courses and program or technical electives)	66/72

Total : 168/177

Schematic Program of Studies

First Semester

FYC 110. Composition	3
History/Social Science*	3
MATH 125. Calculus I	4
CHEM 121. General Chemistry: Fundamental Principles	4
EG 111. Introduction to Engineering Systems I	3
Physical Education	—
	17

Second Semester

University Seminar+	3
PHYS 131. General Physics I	4
MATH 126. Calculus II	4
CHEM 122. General Chemistry: Biological Processes	3
EG 112. Introduction to Engineering Systems II	3
Physical Education	—
	17

Third Semester

Theology/Philosophy	3
Modern Language	3
PHYS 132. General Physics II	4
MATH 225. Calculus III	3.5
AL 211. Ideals, Values and Images	3
Engineering Program†	3
	19.5

Fourth Semester

Theology/Philosophy	3
AL 212. Ideals, Values and Images	3
Modern Language	3
MATH 228. Linear Algebra and Differential Equations	3.5
Engineering Program†	3
Engineering Program	3
	18.5

Fifth Semester

Philosophy/Theology	3
History/Social Science	3
Engineering Program	3
Arts and Letters Major‡	3
Engineering Program	3
Engineering Program	3
	18

Sixth Semester

Philosophy/Theology	3
Arts and Letters Major	3
Arts and Letters Major	3
Engineering Program	3
Engineering Program	3
Engineering Program	3
	18

Seventh Semester

Literature*	3
History/Social Science	3
Engineering Program	3
Engineering Program	3
Engineering Program	3
Arts and Letters Major	3
	18

Eighth Semester

Fine Arts*	3
Engineering Program	3
Engineering Program	3
Arts and Letters Major	3
Engineering Program	3
Engineering Program	3
	18

Ninth Semester

Engineering Program	3
Engineering Program	3
Engineering Program	3
Engineering Program	3
Arts and Letters Major	3
Arts and Letters Major	3
	18

Tenth Semester

Engineering Program	3
Engineering Program	3
Engineering Program	3
Arts and Letters Major	3
Engineering Program	3
	15

+ *The University Seminar may be selected from an appropriate history, social science, fine arts or literature course, or the first course in theology or philosophy.*

* *The University degree requirement is one course in literature or fine arts. The College of Arts and Letters requires a minimum of one course in each subject area, plus one additional course in history or social science.*

** *Two courses in the intermediate or advanced series complete the requirement. Beginning or elementary series require three semesters' work to fulfill the language requirement.*

† *Courses specified by the student's major engineering department. Minimum total for the five-year program to fulfill degree requirements in both colleges is 168 to 177 credit hours.*

‡ *Courses necessary to fulfill the requirements for a major in the student's major arts and letters department.*

DUAL DEGREE PROGRAM WITH THE MENDOZA COLLEGE OF BUSINESS

Coordinators:

Hayden Estrada
Director of admissions
Master of Business Administration Program

John J. Uhran Jr.
Associate dean
College of Engineering

Program of Studies. The dual degree five-year program between the Mendoza College of Business and the College of Engineering enables the student to earn the bachelor of science in a chosen field of the College of Engineering and the master of business administration.

This program, instituted in 1991, offers students the opportunity to better integrate study in engineering and in management. The student completing this program has a background in the management sciences, as well as the first professional degree in one of the fields of engineering. Because it is a demanding program, only those students of superior scholastic ability, who have both the aptitude and motivation necessary for the combined graduate and undergraduate program, should apply. Advisors for the program are available for consultation about the advisability of applying for the program and about meeting the particular needs of each student pursuing this program.

This program is open only to those currently enrolled Notre Dame students who have completed three years of a degree program in the College of Engineering. Students interested in making application for the M.B.A./engineering program should apply to the M.B.A. program during their junior year. To facilitate the application process, students should take the Graduate Management Admission Test (GMAT) either in June following their sophomore year or in October during the fall semester of their junior year.

An applicant who is not admitted to the dual degree engineering/M.B.A. program continues in the undergraduate engineering program and completes his or her undergraduate engineering program in the usual four-year timeframe.

As a general guide, it is expected that a student accepted to this program will take two courses required for the undergraduate degree during the summer session following the junior year. The following schedule of classes is an example of how a program might be accomplished.

First Year, Sophomore Year, Junior Year:

As outlined for individual engineering degree programs in this *Bulletin.* 98–104 credit hours.

Summer Session Following Junior Year:

Arts and Letters course+	3
Arts and Letters course+	3
MBA 503. Excel Workshop**	0
MBA 504. Career Development**	0

Senior Year

First Semester

MGT 500. Statistics	3
FIN 510. Microeconomics*	3
ACCT 500. Accounting	3
MARK 500. Marketing Management	3
MBA 500. Management Communication I	1.5
Engineering courses	6
	16.5

Second Semester

FIN 500. Financial Management	3
FIN 515. Global Macroeconomic Environment	3
MGT 515. Operations Management	3
MBA 501. Management Communication II	1.5
Engineering courses	6
	16.5

Fifth Year

First Semester

FIN 510. Microeconomic Analysis	3
MGT 510. Organizational Behavior	3
Business Ethics Elective	3
International Business Elective	3
Engineering courses	6
	18

Second Semester

MGT 519. Corporate Strategy	3
M.B.A. Electives	12
Engineering course	3
	18

+ *See "Arts and Letters Core" on the first page of the College of Engineering section.*

* *If Statistics is waived.*

** *Occurs during August Orientation.*

Total for both degrees: 126–132 undergraduate, 48 M.B.A.

One M.B.A. course will be accepted as an elective or technical elective in the College of Engineering Programs. No more than two M.B.A. courses may be accepted toward an undergraduate degree from the College of Engineering. Students are advised to check specific program requirements.

Officers of Administration

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STEPHEN E. SILLIMAN, Ph.D.
Associate Dean of the College of Engineering

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Director of Budget and Operations

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