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 has regarded 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.

The College Vision Statement.

- To provide *preeminent education experiences* that are stimulating, responsive to the needs of the 21st century, and prepare our students for leadership in their profession and society.
- To conduct *world-class research* that addresses *critical needs* of society.
- To gain *national recognition* as a first-tier college of engineering.
- To contribute to the *Catholic character* of the University.

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 successfully complete registration as a professional geoscientist.

Programs and Degrees

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

BS in aerospace engineering
BS in chemical engineering
BS in civil engineering
BS in computer engineering
BS in computer science
BS in electrical engineering
BS in environmental geosciences
BS 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 no more than 162 credit hours, depending on the program. 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 Core: 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 10550. Calculus I, MATH 10560. Calculus II, MATH 20550. Calculus III, MATH 20580. Introduction to Linear Algebra and Differential Equations, CHEM 10121. General Chemistry: Fundamental Principles, CHEM 10122. General Chemistry: Biological Processes, PHYS 10310. General Physics I, PHYS 10320. General Physics II, EG 10111, 10112: 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 10550. Calculus I	4
CHEM 10121. General Chemistry: Fundamental Principles	4
Arts and Letters course*	3
EG 10111. Introduction to Engineering Systems I#	3
Physical Education	—
	17

Second Semester

University Seminar+ or Composition	3
MATH 10560. Calculus II	4
CHEM 10122. General Chemistry: Biological Processes	3
PHYS 10310. General Physics I	4
EG 10112. 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 Arts and Letters Core above.*

#While EG 10111–10112 is acceptable for the environmental geosciences degree, it is not required and the sequence ENVG 10110–10100 may be substituted.

General Requirements. The University of Notre Dame reserves the right to change at any time regulations included in its *Bulletin*s 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.

Engineering Honors Program. The College of Engineering has developed an honors program for those students whose achievements have identified them as among the best of entering high school students. This program will provide special opportunities for engineering and scientific research, cultural enrichment, and social leadership over and above what is already available to all. Admission to the program is by invitation and commences in the First Year of Studies with a special yearlong seminar that satisfies two University core requirments. Each student in this program will be guided by a faculty member who functions as his or her research advisor and mentor. Thus, students and faculty meet regularly in both formal and informal settings. To graduate with recognition as an honor student, each student must participate all four years and complete a research thesis in the student's major field in the senior year.

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 degree 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 MBA program.

The general sequence of courses in the five-year engineering-MBA 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, CSC, 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.

The Reilly Scholar Designation. The designation Reilly Scholar is given annually to those fifth-year seniors enrolled in the dual Engineering/Arts and Letters program who have excelled academically and otherwise during their first four years as students. A cash award is also made from a fund set up by Jack Reilly to encourage such interdisciplinary studies.

The AmericoDarin Prize. From a fund set up by the Darin family, in their father's name, a cash award is made to several engineering juniors who have demonstrated exceptional and steady improvement over their first four semesters at Notre Dame.

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 major for outstanding performance in the aerospace deisgn course.

Sigma Gamma Tau Honor Award. Presented each year to a member of the Notre Dame chapter in recognition of outstanding academic performance and demonstrated professional potential.

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.

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

The Rockwell Automation Power Systems Design Award. Presented each year to seniors in mechanical engineering for the best design in the senior mechanical engineering design course.

CHEMICAL AND BIOMOLECULAR ENGINEERING

AIChE Scholarship Award. A certificate and a copy of Perry's Chemical Engineers' Handbook awarded to the junior chemical 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 student considered to have performed outstanding undergraduate research.

CIVIL ENGINEERING AND GEOLOGICAL SCIENCES

The American Society of Civil Engineers. The Indiana section each year presents 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, CSC, 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.

StudentOrganizations 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 National Society of Black Engineers
The Society of Professional Hispanic Engineers
The Society of Women 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
Viola D. Hank Professor of Mechanical Engineering:
Hafiz M. Atassi
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); James J. Mason; Stuart T. McComas (emeritus); Thomas J. Mueller (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); Joseph M. Powers; Steven R. Schmid; Michael M. Stanisic
Assistant Professors:
Alan P. Bowling; James E. Houghton (emeritus); Katherine Wenjun Liu; Scott C. Morris; Glen L. Niebur; Ryan K. Roeder
Associate Professional Specialist:
Rodney L. McClain; Richard B. Strebinger

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 ame.nd.edu. 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.

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 engineering sciences, design and experimental methods. Some specialization in specific areas 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 engineering practice—the kinds of things aerospace engineers do, the kinds of problems they solve, especially a breadth of familiarity with aerospace systems and designs such as those 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, including aircraft and spacecraft 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; and 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; and are able 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, are able to apply high ethical and professional standards.

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 20550. Calculus III	3.5
PHYS 10320. General Physics II	4
AME 20221. Mechanics I	3
AME 20211. Introduction to Aeronautics	3
Arts and Letters course+	3
	16.5

Second Semester

MATH 20580. Introduction to Linear Algebra and Differential Equations	3.5
AME 20222. Mechanics II	3
AME 20241. Solid Mechanics	4
AME 20231. Thermodynamics	3
AME 20213. Measurements and Data Analysis or AME 30361. Computer Aided Design and Manufacturing	3
	16.5

Junior Year
First Semester

AME 30314. Differential Equations, Vibrations and Controls I	3
AME 20213. Measurements and Data Analysis or AME 30361.Computer Aided Design and Manufacturing	3
AME 30341. Aerospace Structures	3
AME 30331. Fluid Mechanics	3
Arts and Letters course+	3
	15

Second Semester

AME 30315. Differential Equations, Vibrations and Controls II	3
AME 30333. Aerodynamics Laboratory	4
AME 30332. Compressible Aerodynamics	3
AME 30334. Heat Transfer	3
Arts and Letters course+	3
	16

Senior Year
First Semester

AME 40461. Flight Mechanics and Introduction to Design	3
AME 40451. Aerospace Dynamics	3
AME 40431. Gas Turbines and Propulsion	3
Technical Specialization*	3
Arts and Letters course+	3
	15

Second Semester

AME 30381. Orbital and Space Dynamics	3
AME 40462. 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.

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

+ 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 website.

The most current information for the degree program course requirements is available on the department website: (ame.nd.edu).

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 use of a computer in many 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 ame.nd.edu. 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.

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 specific 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, and 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 essential function of common sensor types and are experienced in acquiring digital data from a range of tranducers; 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; are 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 in both 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, are able to apply high ethical and professional standards.

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 20550. Calculus III	3.5
PHYS 10320. General Physics II	4
AME 20221. Mechanics I	3
AME 20212. Introduction to Mechanical Engineering	3
Arts and Letters course+	3
	16.5

Second Semester

MATH 20580. Introduction to Linear Algebra and Differential Equations	3.5
AME 20222. Mechanics II	3
AME 20241. Solid Mechanics	4
AME 20213. Measurements and Data Analysis or AME 30361. Computer Aided Design and Manufacturing	3
AME 20231. Thermodynamics	3
	16.5

Junior Year
First Semester

AME 30314. Differential Equations, Vibrations and Controls I	3
AME 20213. Measurements and Data Analysis or AME 30361 Computer Aided Design and Manufacturing	3
AME 30331. Fluid Mechanics	3
AME 30363. Design of Machine Elements	3
Arts and Letters course+	3
	15

Second Semester

AME 30315. Differential Equations, Vibrations and Controls II	3
AME 30334. Heat Transfer	3
AME 30362. Design Methodology	3
EE 20224. Introduction to Electrical Engineering	4
Arts and Letters course+	3
	16

Senior Year

First Semester

CBE 30361. Science of Engineering Materials	3
AME 40463. Senior Design Project	4
AME 40423. 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

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

+ *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 website.*

The most current information for the degree program course requirements is available on the department website: (ame.nd.edu).

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.

AME 20211. Introduction to Aeronautics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): AME 21211
An introduction to the fundamental concepts in fluid mechanics, the science of flight, the atmosphere, and airplane aerodynamics. Applications of the principles of mechanics to aircraft flight performance, stability, control, and design. Fall.

AME 21211. Intro to Aeronautics Lab
(0-1-0)
Corequisite(s): AME 20211
1 hour computing lab for Introduction to Aeronautics

AME 20212. Introduction to Mechanical Engineering
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): AME 21212
An introduction to the discipline of mechanical engineering. Application and integration of the varied mechanical engineering subdisciplines to practical case studies. Fall.

AME 21212. Introduction to Mechanical Engineering Lab
(0-1-0)
Corequisite(s): AME 20212
One hour computing lab for Introduction to Mechanical Engineering

AME 20213. Measurements and Data Analysis
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): AME 21213
Introduction to experimental methods used in aerospace and mechanical engineering, including basic instrumentation, data acquisition, and data analysis techniques. Embedded microprocessors may be used for data acquisition and/or control. Fall and spring.

AME 20221. Mechanics I
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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.

AME 20222. Mechanics II
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Introduction to Newtonian dynamics. Kinematics and kinetics (energy, linear, and angular momenta) of particles, systems of particles, and rigid bodies. Spring.

AME 20231. Thermodynamics
(3-0-3)
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. Spring.

AME 20241. Solid Mechanics
(4-0-4)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): AME 21241
Introduction to the concepts of stress and strain, material properties, deflections of bars under axial, torsional, and bending loads, statically indeterminate problems, and stress transformations, including related experimental laboratory exercises. Spring.

AME 21213. Measurement and Data Analysis Lab
(0-3-0)
Corequisite(s): AME 20213
This laboratory gives students experimental exposure to various techniques for collecting data used in aerospace and mechanical engineering.

AME 21241. Solid Mechanics Lab
(0-3-0)
Corequisite(s): AME 20241
Co-requisite for Solid Mechanics.

AME 30314. Differential Equations, Vibrations, and Control I
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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, single-degree of freedom vibrations, numerical solutions to systems of ordinary differential equations, and partial differential equations. Fall.

AME 30315. Differential Equations, Vibrations, and Control II
(3-0-3)
Prerequisite(s): (AME 30314 or AME 301)
Systems of nth-order differential equations, multiple-degree of feedom vibrations, linear feedback s-plane controls analysis, and frequency response analysis. Spring.

AME 30331. Fluid Mechanics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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.

AME 30332. Compressible Aerodynamics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
An intermediate course of the study of the dynamics and thermodynamics of compressible flow for both internal and external geometries, including boundary layer effects. Applications of compressible flow principles to propulsive nozzles, flight simulation facilities, and supersonic airfoil problems. Spring.

AME 30333. Aerodynamics Laboratory
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Use and operation of a subsonic wind tunnel, flow velocity, pressure and strain gauge measurements, data acquisition and analysis, with emphasis on interpretation of aerodynamic flow phenomena. Spring.

AME 30334. Heat Transfer
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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.

AME 30341. Aerospace Structures
(3-0-3)
Prerequisite(s): (AME 20241 or AME 238)
A study of basic principles and methods for structural analysis of lightweight structures with emphasis on aerospace applications. An introduction to load analysis of aircraft, materials, fatigue, stress/deformation analysis of thin-walled structures, and

aeroelasticity. Fall.

AME 30361. Computer-Aided Design and Manufacturing
(3-0-3)
Principles of engineering-graphic communications: visualization, sketching, orthographic projection, principal and auxiliary projections, 3-D surfaces, and feature-based design. Geometric dimensioning and tolerancing, computer-integrated manufacturing, and rapid prototyping. Fall and spring.

AME 30362. Design Methodology
(3-0-3)
Modeling and analysis of mechanical systems. Automated design decision process, introduction to statistical methods, material engineering, requirements definition, and product specifications. Spring.

AME 30363. Design of Machine Elements
(3-0-3)
Prerequisite(s): (AME 20241 or AME 238)
Corequisite(s): AME 32363
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.

AME 30381. Orbital and Space Dynamics
(3-0-3)
Prerequisite(s): (AME 20222 or 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.

AME 32363. Design of Machine Elements Recitation
(0-0-0)
Corequisite(s): AME 30363
Weekly recitation for Design of Machine Elements

AME 36099. Directed Readings
(V-0-V)
Individual or small group study under the director of a faculty member in an undergraduate subject not currently covered by any University course. As needed.

AME 40423. Mechanisms and Machines
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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.

AME 40431. Gas Turbines and Propulsion
(3-0-3)
Prerequisite(s): (AME 30331 or AME 330)
The mechanics and thermodynamics of gas turbines and air-breathing propulsion devices. The mechanics of various space propulsion systems are also presented, including an introduction to rocket propulsion. Fall.

AME 47099. Special Studies
(V-0-V)
Individual or small group study under the direction of a faculty member in an undergraduate subject not currently covered by any University course. As needed.

AME 40451. Aerospace Dynamics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Mechanics and equations of motion, aerodynamics forces, airplane motions, longitudinal and lateral. Introduction to autopilot design. Fall.

AME 40461. Flight Mechanics and Introduction to Design
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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.

AME 40462. Aerospace Design
(4-0-4)
Prerequisite(s): (AME 40461 or 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.

AME 40463. Senior Design Project
(3-0-4)
Corequisite(s): AME 41463
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.

AME 41463. ME Senior Design Lab
(0-4-0)
Corequisite(s): AME 40463
Lab section of the senior design course

AME 47431. Independent Study in Heat Transfer
(0-0-3)
An independent, directed study course that covers the three modes of heat transfer: steady and unsteady conduction, elementary boundary layer analysis for laminar and turbulent convection and the basic theory of radiation. This course is equivalent in content to AME 30334.

AME 48491. Undergraduate Research
(V-0-V)
A research project at the undergraduate level under the supervision of a faculty member. Fall and spring.

AME 50521. Intermediate Dynamics
(3-0-3)
Prerequisite(s): AME 20222 or AME 226
Review of linear algebra, 3-D rigid body dynamics: kinematics and kinetics; the gyroscope. analytical dynamics: constraints and Lagrangian dynamics; Hamiltonian dynamics and canonical transformations.

AME 50531. Intermediate Thermodynamics
(3-0-3)
Prerequisite(s): AME 20231 or AME 327
A second course in engineering thermodynamics including cycle analyses, real gas behavior, psychometrics, gas mixtures, chemical equilibrium and finite-rate chemical reactions, elements of compressible flow.

AME 50532. Computational Fluid Dynamics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
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.

AME 50541. Finite Element Methods for Structural Analysis
(3-0-3)
Prerequisite(s): (AME 20241 or AME 238)
An introduction to the finite element method with applications to problems in structural analysis. Basics of linear and non-linear finite element formulation and programming, applications to bars, beams, and simple continuum problems, use of commercially available codes with advanced input/output capabilities.

AME 50542. Engineering Analysis of Manufacturing Processes
(3-0-3)
Kinematics of 2-D and 3-D robots; statics and dynamics; design considerations; actuators; sensors; and control fundamentals. Project assignments are used to demonstrate the fundamentals of robotics.

AME 50551. Introduction to Robotics
(3-0-3)
Prerequisite(s): (AME 30314 or AME 301)
Kinematics of 2-D and 3-D robots; statics and dynamics; design considerations; actuators; sensors; and control fundamentals. Project assignments are used to demonstrate the fundamentals of robotics.

AME 50561. Reliability Engineering
(3-0-3)
An introduction to fundamental concepts in reliability analysis that includes statistical concepts, data and data distributions, reliability analysis of data, quality concepts including Taguchi methods, analysis of maintained systems, human failure interaction and fault tree analysis.

AME 50562. Advanced Design Project
(3-0-3)
Prerequisite(s): (AME 40463 or AME 470 or AME 470A or AME 470B)
A course to provide a student with the opportunity to pursue a more advanced design topic or in-depth project that was started in AME 40463. Requires department approval at the beginning of the senior year. As needed.

AME 50581. Space Systems and Analysis
(3-0-3)
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.

AME 50591. Failure and Risk in Engineering
(3-0-3)
Assessing risk and predicting the effects of failure is an important part of engineering. These are influenced by the manner in which engineers develop, evaluate, and use information in making decisions. Engineering decisions are also influenced by ethical and legal considerations in the forms of codes, regulations, and standards. This course will address selected ethical, legal, and technical issues related to the failure of engineering systems and include specific case studies.

AME 60655. Intelligent Systems
(3-0-3)
This course will introduce seniors to a unified view of the aerospace and mechanical engineering applications of intelligent systems theory and practice.

A number of introductory graduate-level courses, described in the *Graduate School Bulletin of Information* and on the department website, 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; William F. Schneider
Assistant Professors:
Agnes E. Ostafin; Andre F. Palmer; Y. Elaine Zhu
Research Professors:
Alexander S. Mukasyan
Assistant Research Professor:
Sudhir Aki; Zilin Chen
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 other than 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 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 20550. Calculus III	3.5
CHEM 20223. Organic Chemistry	3
CHEM 21223. Organic Chemistry Lab I	1
PHYS 10320. General Physics II	4
CBE 20255. Introduction to Chemical Engineering Analysis	3
Arts and Letters Course+	3
	17.5

Second Semester

CHEM 20224. Organic Chemistry II	3
MATH 20580. Introduction to Linear Algebra and Differential Equations	3.5
CBE 20256. Chemical Engineering Thermodynamics	4
CBE 20258. Computer Methods in Chemical Engineering	3
Arts and Letters course+	3
	16.5

Junior Year

First Semester

MATH 30650. Differential Equations	3
CHEM 30333. Analytical Chemistry	2
CHEM 31333. Analytical Chemistry Lab	2
CBE 30361. Science of Engineering Materials	3
CBE 30355. Transport Phenomena I	3
Arts and Letters course+	3
	16

Second Semester

CHEM 30324. Physical Chemistry	3
CBE 30356. Transport Phenomena II	3
CBE 31358. Chemical Engineering Laboratory I	3
CBE 30338. Chemical Process Control	3
Elective	3
Arts and Letters course+	3
	18

Senior Year

First Semester

CBE 41459. Chemical Engineering Laboratory II	3
CBE 40443. Separation Processes	3
CBE 40445. Chemical Reaction Engineering	3
Advanced Science Elective*	3
Chemical Engineering Elective*	3
	15

Second Semester

Chemical Engineering Elective*	3
CBE 40448. Chemical Process Design	3
Technical Elective*	3
Technical 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 website.*

+ *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.

CBE 20255. Introduction to Chemical Engineering Analysis
(3-0-3) McCready
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.

CBE 22255. Introduction to Chemical Engineering Tutorial
(1-0-0)
Tutorial for Introduction to Chemical Engineering.

CBE 20256. Chemical Engineering Thermodynamics
(4-0-4)
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.

CBE 20258. Computer Methods in Chemical Engineering
(3-0-3)
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.

CBE 20290. Career Choices for Engineers
(1-0-1)
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.

CBE 30327. Thermodynamics
(3-0-3)
Basic concepts of thermodynamics, temperature, pressure, volume, state equations, and thermodynamic properties of substances. The first law of thermodynamics, kinetic energy, potential energy, internal energy, work heat, and flow volume work balances in steady state and transient processes. The second law of thermodynamics, heat engines, lost work, and entropy balances. Thermodynamic diagrams, corresponding states, residual properties of high pressure gases, liquid state correlations, and changes of phase. Applications to the flow of liquids, power production, compressors, motive power engines, refrigeration, and other basic engineering systems

CBE 32327. Thermodynamics Tutorial
(1-0-0)
Tutorial for Thermodynamics.

CBE 30338. Chemical Process Control
(3-0-3)
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.

CBE 32338. Chemical Process Control Tutorial
(1-0-0)
Tutorial for Chemical Process Control.

CBE 30343. Chemical Engineering Thermodynamics
(3-0-3)
The old second thermodynamics course. It contained phase equilibria and chemical equilibria.

CBE 30355. Transport Phenomena I
(3-0-3) Leighton
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.

CBE 32355. Transport Phenomena I Tutorial
(1-0-0)
Tutorial for Transport Phenomena I

CBE 30356. Transport Phenomena II
(3-0-3) Zhu
Integral and differential transport equations are applied to the solution of heat and mass transfer problems of interest to chemical engineers.

CBE 30361. Science of Engineering Materials
(3-0-3) Mukasyan
Prerequisite(s): see online Course Catalog for details.
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.

CBE 31358. Chemical Engineering Laboratory I

(1-4-3) Saddawi

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.

CBE 32356. Transport Phenomena II Tutorial

(0-1-0)

Corequisite(s): CBE 30356

Tutorial for Transport Phenomena II.

CBE 40439. Simulation and Optimization

(3-0-3) Stadtherr

This course will provide an overview of the computational methodologies used for chemical process simulation and optimization. Topics will include: (1) how to formulate process models; (2) how to solve process models (linear and nonlinear equation solving, etc.); and (3) how to optimize using process models (linear and nonlinear programming, global optimization, etc.).

CBE 40443. Separation Processes

(3-0-3) Maginn

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.

CBE 40445. Chemical Reaction Engineering

(3-0-3) Schneider

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.

CBE 40448. Chemical Process Design

(3-0-3) Stadtherr

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).

CBE 40461. Structure of Solids

(3-0-3) McGinn

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.

CBE 40464. Principals of Materials Selection

(3-0-3) Miller

Case study based course focuses on systematically selecting the appropriate material (metal, ceramic, polymer, or composite), its method of processing and fabrication, and all associated costs to achieve an optimized choice for a given shape. The student will learn to use a powerful computer search and database system (Cambridge Engineering Selector) to rapidly achieve an optimized materials selection for a wide variety of mechanical designs.

CBE 40465. Intermolecular Forces

(3-0-3) Zhu

This course will discuss experimental and theoretical techniques for understanding intermolecular forces.

CBE 40472. Modeling - Ecology and Environment

(3-0-3) Stadtherr

This course covers various topics pertaining to the Earth's ecological and biogeochemical systems and the effects of disturbances or imbalances, particularly those caused by human/industrial activities. Based on fundamentals incorporated in such subject areas as chemical reaction engineering, process dynamics, and transport phenomena, the principal topics center on population and ecosystem dynamics, and on the Earth's natural and altered environments. Examples and applications are drawn from such subjects as the endangerment or extinction of species, biogeochemical cycles, greenhouse gases and global warming, ozone pollution in the troposphere and depletion in the stratosphere, pollutant dispersion, and acid rain. The course makes extensive use of methods of mathematical modeling, nonlinear dynamics, and computer simulations. In major course assignments, students work in small groups on modeling/simulation projects.

CBE 40474. Environmental Design

(3-0-3) Brennecke

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 homework, 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.

CBE 40476. Global Climate Change

(3-0-3) McCready

This course integrates the principles of physical sciences and engineering as they pertain to the environment, with addition discussion of social, political, and theological concerns. We analyze the complex couplings and feedback mechanisms that operate between the geosphere, the biosphere, the atmosphere, and the hydrosphere as related to global climate changes.

CBE 40481. Biomedical Engineering Transport Phenomena

(3-0-3) Palmer

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.

CBE 40482. Biomaterials Engineering

(3-0-3) Ostafin

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.

CBE 40484. Bioprocess Engineering

(3-0-3) Ostafin

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.

CBE 40564. Principles of Materials Selection
(3-0-3)
One of the most important tasks that an engineer may be called upon to perform is that of materials selection with regard to component design. It is essential that the engineering student become familiar with and versed in the procedures and protocols that are normally employed in this process. This course will discuss materials selection issues in several contexts and from various perspectives. A case study method will be used to frame real-life engineering problems so that they can be carefully analyzed in detail so that the student may observe the procedures and rationale that are involved in the materials selection decision-making process. Mechanical, IC packaging, and corrosion case studies, in addition to others, will be used.

CBE 40901. Corporate Ethics and Values
(3-0-3)
This seminar examines the role of the individual in the corporate environment. Guidelines for career growth, interpersonal relationships, skilled communications, and ethical responsibility in corporate affairs are analyzed and enforced.

CBE 40911. Fuel Cells Science and Technology
(3-0-3) Miller
Principles of the conversion of electrochemical energy to electrical power and the engineering requirements of an operating fuel cell.

CBE 40913. Macromolecular Bioengineering
(3-0-3)
Recent advances in molecular biology have made it possible to study biological macromolecules thoroughly and provide large quantities of samples necessary to find their use in practical applications. Macromolecules are very small, but can perform many important functions, such as information transfer, catalysis, energy acquisition, transport regulation, and even generate energy. In this course we will study these unique characteristics of macromolecules and seek how they can contribute in the area of engineering, such as developing nanoscale devices, innovative materials, information storage devices, energy capture and storage, and many other applications.

CBE 40916. Biological Dynamics and Diagnostics
(3-0-3)
This course will examine physiology phenomena such as cardiac rhythms, bacterial detection/diagnostics, neuron signal transmission, blood circulation, pulmonary airflow, and more general biological topics such as ion channels, actin motors, and genomic sequences from the viewpoint of mathematical analysis. Explicit and implicit patterns and organized dynamic will be elucidated and used to provide insight into the underlying physiology or biology.

CBE 41362. Laboratory Technology in Materials Science
(0-3-1) Maginn
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.

CBE 41459. Chemical Engineering Laboratory II
(1-4-3) Saddawi
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.

CBE 41910. Biomolecular Engineering Lab
(0-4-3) Ostafiin
In this course students will be exposed to modern laboratory methods in bioengineering and experimental design. Students will be expected to develop and execute laboratory protocols, write laboratory reports, and present orally their findings.

CBE 42445. Chemical Reaction Engineering Tutorial
(1-0-0)
Tutorial for Chemical Reaction Engineering

CBE 45490. Internship Experience
(0-0-V)
Intended to facilitate interactions between Notre Dame and Industry by allowing students to get credit for internship experience.

CBE 46497. Directed Readings
(V-0-V)
Course requires the student to explore various readings chosen by the professor.

CBE 48901. Undergraduate Research
(V-0-V)
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.

CBE 48902. Advanced Undergraduate Research
(0-12-3)
This course is intended for students with previous research experience and requires at least one credit of 40901 as a prerequisite. It requires a written final report. This course will count as a technical or engineering elective.

CBE 48901. Undergraduate Research
(0-0-V)
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.

CBE 48903. Undergraduate Thesis
(0-12-2)
This course requires a written thesis document that is defended to a committee of faculty. At least one credit of 48901 research is a prerequisite, although several semesters are recommended. This course will count in place of a chemical engineering elective.

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

60542. Mathematical Methods Engineering I
50510. Advanced Chemical Engineering Thermodynamics
30355. Transport Phenomena I
40445. 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); Kenneth R. Lauer (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, CSC (emeritus); Joannes J.A. Westerink
Assistant Professors:
Tracy L. Kijewski-Correa; Robert Nerenberg; Susan E.H. Sakimoto; Lynn A. Salvati; Jeffrey W. Talley; Wilasa Vichit-Vadakan; Jennifer R. Woertz

Vision and Mission. The Department of Civil Engineering and Geological Sciences (CE/GEOS) 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/GEOS strives to provide a stimulating and unique interdisciplinary environment for learning and research by blending traditional disciplines of engineering and science.

CE/GEOS offers outstanding educational programs for those aspiring to contribute as leaders in the fields of Civil Engineering, Environmental Engineering, and Environmental Geosciences. CE/GEOS'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 resource/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; and a number of analytical laboratories for water, wastewater and hazardous waste treatment.

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 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 20550. Calculus III	3.5
PHYS 10320. General Physics II	4
CE 20150. Mechanics I	3
CE 20130. Methods of Civil Engineering	4
	14.5

Second Semester

MATH 20580. Introduction to Linear Algebra and Differential Equations	3.5
MATH 30440. Probability and Statistics	3
AME 20241. Solid Mechanics	4
CE 20500. Engineering Geology	3
Arts and Letters course*	3
	16.5

Junior Year

First Semester

MATH 30650. Differential Equations	3
CE 30200. Intro to Struc. Engrg.	3
CE 30300. Intro to Env. Engrg.	3
CE 30125. Computational Methods	3
Arts and Letters course+	3
	15

Second Semester

CE 30160. Materials	4
CE 30510. Intro Geotech Engrg	4
CE 30210. Structural Analysis (Opt A)**	(3)
CE 30320. Water Treat & Chem. (Opt B)**	(3)
CE 30460. Fluid Mechanics	3
Arts and Letters course+	3
	17

Senior Year

First Semester

CE 40450. Hydraulics	3
CE 40270. Reinf. Concrete Design (Opt A)**	(4)
CE 40460. Groundwater Hydrology (Opt B)**	(4)
Civil Engineering elective	3
FreeeElective	3
Arts and Letters course+	3
	16

Second Semester

CE 40620. Transportation Engineering	3
CE 40280. Structural Steel Design (Opt A)**	(4)
CE 40340. Wastewater Disp. (Opt B)**	(4)
Civil Engineering elective	3
Technical elective	3
Arts and Letters course+	3
	16
Total degree required credits	129

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

***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.

CE 20130. Methods of Civil Engineering Analysis

(4-0-4) Vichit-Vadakan

Corequisite(s): CE 21130

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. Fall.

CE 21130. Methods/Civil Engineering Analysis Lab

(0-1-0)

Corequisite(s): CE 20130

The concurrent laboratory portion of CE 20130. Fall.

CE 20150. Mechanics I

(3-0-3) Kirkner

Prerequisite(s): see online Course Catalog for details.

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.

CE 20500. Engineering Geology

(3-0-3) Burns

A study of physical geology and geologic processes relevant to engineering. Emphasis is on 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. Spring.

CE 25600. Civil Engineering Service Projects

(V-0-V) Ketchum

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. These projects have a civil engineering emphasis, but benefit from enrollment of most other undergraduate majors. Fall and spring.

CE 30125. Computational Methods
(3-0-3) Westerink
Fundamentals of numerical methods and development of programming techniques to solve problems in civil and environmental engineering. This 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 solutions to 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. Fall.

CE 30160. Civil Engineering Materials
(3-0-4) Vichit-Vandakam
Corequisite(s): CE 31160
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. Spring

CE 31160. Mechanics of Solids/Materials Laboratory
(0-1-0)
Corequisite(s): CE 30160
The concurrent laboratory portion of CE 30130. Fall.

CE 32160. Civ Engr. Materials Tutorial
(0-1-0)
The concurrent tutorial portion of CE 30-130. Fall.

CE 30200. Introduction to Structural Engineering
(3-0-3) Kareem
Prerequisite(s): (AME 20241 or 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 codes and standards. Fall.

CE 30210. Structural Analysis
(3-0-3)
Prerequisite(s): (CE 30200 or 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. The first course in the structures track. Spring.

CE 30300. Introduction to Environmental Engineering
(3-0-3) Talley
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. The first course in the environmental track. Fall.

CE 30320. Water Chemistry and Treatment
(3-0-3)
An introduction to water treatment design, including discussion of basic aquatic chemistry, water quality, environmental policy, and current issues and problems in the industry. The first course in the environmental track. Spring.

CE 30510. Geotechnical Engineering
(3-0-4)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CE 31510
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. Spring.

CE 31510. Geotechnical Engineering Lab
(0-1-0)
Prerequisite(s): (AME 20221 or AME 225)
Corequisite(s): CE 30510
The concurrent laboratory portion of CE 30500. Spring.

CE 35600. Civil Engineering Service Projects
(V-0-V) Ketchum
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. These projects have a civil engineering emphasis, but benefit from enrollment of most other undergraduate majors. Fall and spring.

CE 40120. Numerical Methods in Engineering
(3-0-3) Westerink
Prerequisite(s): (MATH 30650 or MATH 325)
Finite difference and finite element methods for the solution of ordinary and partial differential equations encountered in engineering. Spring.

CE 40170. Advanced Mechanics of Solids
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
The course covers fundamental principles and techniques in stress analysis of trusses, beams, rigid frames, and thin-walled structures. Emphasis is placed on energy methods associated with calculus of variations. Offered as needed.

CE 40270. Reinforced Concrete Design
(3-1-4) Kurama
Prerequisite(s): (CE 30200 or 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. The second or third course in the structures track. Alternates fall and spring.

CE 40275. Prestressed Concrete Design
(3-0-3)
Prerequisite(s): CE 40270 or CE 486
Mechanics of prestressed concrete structural members. Design of prestressed concrete structural members and simple systems. Strength and serviceability considerations.

CE 40280. Structural Steel Design
(3-1-4)
Prerequisite(s): (CE 30200 or CE 336)
Corequisite(s): CE 40605
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 structural steel residential/commercial building. The second or third course in the structures track. Alternates fall and spring.

CE 40320. Environmental Chemistry
(3-0-3) Maurice
Application of acid-base, solubility, complex formation, and oxidation reduction equilibria to water supply, wastewater treatment, and natural environmental systems. Fall.

CE 40340. Waste Treatment
(3-0-4) Nerenberg
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. The third course in the environmental track. Spring.

CE 42340. Waste Treatment Tutorial
(0-1-0)
The concurrent tutorial portion of CE 40340.

CE 40350. 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. Spring.

CE 40385. Hazardous Waste Management and Design
(3-1-4)
The course addresses traditional and innovative technologies, concepts, and principles applied to hazardous waste management and design to protect

human health and the environment. Topics include the regulatory process, fate and transport of contaminants, toxicology, environmental audits, waste minimization, physicochemical processes, bioremediation, stabilization, incineration, land disposal, risk assessment, remedial investigations, remedial technologies, and alternative analysis. Course will include a remediation design project, which may require laboratory analyses.

CE 40450. Hydraulics
(3-0-3) Ketchum
Prerequisite(s): see online Course Catalog for details.
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. Fall.

CE 40460. Groundwater Hydrology
(3-0-4) Silliman
Lectures and laboratory cover the fundamentals of flow and transport in porous media. Methods of analysis for development of groundwater resources. Fall.

CE 41460. Groundwater Hydrology Lab
(0-1-0)
The concurrent laboratory portion of CE 40460. Fall.

CE 40530. Foundation Analysis and Design
(3-0-3) Salvati
Prerequisite(s): see online Course Catalog for details.
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.

CE 40610. Construction Management
(3-0-3)
Engineering aspects of planning, economics, practices, and equipment usage in construction of civil engineering projects. Use of critical path construction schedules. Offered as needed.

CE 40620. Transportation Engineering
(3-0-3)
The planning, design, operation, safety, and economics of transportation systems. Spring.

CE 40627. Global Climate Change
(3-0-3)
A study of the global climate change mechanisms.

CE 45600. Civil Engineering Service Projects
(V-0-V)
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. These projects have a civil engineering emphasis, but benefit from enrollment of most other undergraduate majors. Fall and spring.

CE 47600. Special Studies
(V V-V)
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

CE 48600. Undergraduate Research
(V-0-V)
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.

60130. Finite Elements in Engineering
60210. Advanced Geostatistics
60250. Advanced Structural Dynamics
60330. Environmental Biotechnology
60346. Design of Biological Waste Treatment Systems
60450. Advanced Hydraulics
70290. Behavior and Design of Earthquake-Resistant Structures

* Courses having a 40000/60000 option will require additional work at the 60000 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 (MS, PhD) 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 state-registered geologists in states requiring such certification. Graduates with a BS 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 20110. Physical Geology + Lab	4
ENVG 20200. Mineralogy	4
PHYS 10320. Physics II	4
MATH 20550. Calculus III	3.5
	15.5

Second Semester

ENVG 20120. Historical Geology	4
ENVG 20210. Ign. and Meta. Petrology	4
MATH 20580. Linear Alg. Diff. Equations	3.5
Arts and Letters course[3]	3
ENVG 45200. Field Trip	1
	15.5

Junior Year

First Semester

ENVG 30230. Sediment and Stratigraphy	4
ENVG 40300. Geochemistry	3
Arts and Letters course[3]	3
Free elective	3
Technical elective[2]	3
	16

Second Semester

ENVG 30400. Str. Geology and Rock Mech.	4
ENVG 30300. Surficial Proc. Surf. Hydrol.	3
MATH 20340. Introductory Statistics	3
Arts and Letters course[3]	3
ENVG 45200. Field Trip	1
	14

Senior Year

First Semester

ENVG 40310. Env. Imp. Res. Utilization	3
CE 40320. Environmental Chemistry	3
CE 40460. Groundwater Hydrology	4
Arts and Letters course[3]	3
Arts and Letters course[3]	3
	16

Second Semester

ENVG 40320. Environmental Mineralogy	3
ENVG 40340. Water-Rock Interaction	3
ENVG 40360. 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 10110. Physical Geology + Lab	4
CHEM 10117. General Chemistry I[1]	4
MATH 10550. Calculus I	4
Arts and Letters course[3]	3
FYC 13100[3]	3
Physical Education	0
	18

Second Semester

ENVG 10100. Environmental Geosciences	3
CHEM 10116. General Chemistry II[1]	4
MATH 10560. Calculus II	4
PHYS 10310. Physics I	4
Arts and Letters Course	3
Physical Education	0
	17

Sophomore Year

First Semester

Arts and Letters Course[3]	3
ENVG 20201. Mineralogy	4
PHYS 10320. Physics II	4
MATH 20550. 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 10110. Physical Geology + lab	4
ENVG 20120. Historical Geology	4
ENVG 20200. Mineralogy	4
ENVG 45200. Field Trip	1
Subtotal:	13

One of:

ENVG 20210. Petrology	4
ENVG 30400. Str. Geology and Rock Mech.	4
ENVG 30230. Sediment. and Stratigraphy	4
Subtotal:	4

Two of:

ENVG 30300. Surficial Proc. Surf. Hydrol.	3
ENVG 40300. Geochemistry	3
ENVG 40310. Env. Imp. Res. Utilization	3
ENVG 40380. Environmental Geochemistry	3
ENVG 40380. Paleontology	3
ENVG 40320. Environmental Mineralogy	3
ENVG 40340. Water-Rock Interaction	3
ENVG 40360. Geomicrobiology	3
Subtotal:	6

Total for the minor: 23 semester hours.

Notes:

1. CHEM 10113, 10115, OR 10125 may be substituted for CHEM 10117; CHEM 10118 or 10126 may be substituted for CHEM 10116.
2. Technical electives are typically 30000- and 40000-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 40410. Geophysics
ENVG 40350. Paleontology
ENVG 48600. Undergraduate Research
CHEM 20223. Elem. Organic Chem. I
CHEM 20224. Elem. Organic Chem. II
CHEM 20235. Organic Chemistry + Lab
CHEM 20236. Organic Chemistry + Lab
CHEM 20243. Inorganic Chemistry
CHEM 30321. Physical Chemistry
CHEM 30322. Physical Chemistry II
CHEM 30333. Analytical Chemistry + Lab
CHEM 30341. Fundamentals of Biochemistry
CHEM 40420. Principles of Biochemistry
BIOS 10155. Biological Sciences I
BIOS 10156. Biological Sciences II
BIOS 20201. General Biology I
BIOS 20202. General Biology II
BIOS 30401. Principles of Microbiology
CE 20150. Mechanics I
AME 20222. Mechanics II
AME 30331. Fluid Mechanics
CE 40450. Hydraulics
CE 30320. Int. Water Chem. and Treatment
CE 40340. Waste Treatmentl
MATH 30650. Differential Equations

3. See "Arts and Letters Core" on the first page of the College of Engineering section.
4. If Physical Geology is a required course for a science major, it may also be counted for the minor in Environmental Geosciences.

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.

ENVG 10100. Environmental Geosciences
(3-0-3) Neal
Prerequisite(s): see online Course Catalog for details.
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.

ENVG 10110. Physical Geology
(3-0-4) Neal
Corequisite(s): ENVG 11110
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.

ENVG 11110. Physical Geology Laboratory
(0-1-0)
Corequisite(s): ENVG 10110
This is the laboratory portion of ENVG 10110.

ENVG 20110. Physical Geology
(3-1-4) Neal
Corequisite(s): ENVG 21110
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.

ENVG 20120. Historical Geology
(3-1-4) Rigby
Corequisite(s): ENVG 21120
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.

ENVG 21110. Physical Geology Laboratory
(0-1-0)
Corequisite(s): ENVG 20110
This is the laboratory portion of ENVG 20110.

ENVG 20200. Mineralogy and Optical Mineralogy
(3-1-4) Burns
Crystallography and mineral optics: physical and chemical mineralogy-its application to mineral identification in hand-specimen and using the petrographic microscope.

ENVG 21120. Historical Geology Laboratory
(0-1-0)
Corequisite(s): ENVG 20120
This is the laboratory portion of ENVG 20120.

ENVG 30230. Sedimentation and Stratigraphy
(3-1-4) Rigby
Prerequisite(s): (ENVG 20200 or ENVG 242)
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.

ENVG 40300. Geochemistry
(3-0-3) Fein
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.

ENVG 40380. Paleontology
(2-2-3) Rigby
Prerequisite(s): see online Course Catalog for details.
The fossil record—morphology, taxonomy, evolution, statistical population systematics and paleoecology. A one-day field trip is required.

ENVG 40410. Geophysics
(2-1-3) Sakimoto
Prerequisite(s): (PHYS 10320 or PHYS 132)
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.

ENVG 47600. Special Studies
(V V-V)
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

ENVG 48600. Undergraduate Research
(0 V-V)
Arranged individually for each student.

Computer Science and Engineering

Schubmehl/Prein Department 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); Jesús A. Izaguirre; John J. Uhran Jr., Sr. Associate Dean
Associate Professors:
Jay B. Brockman; X. Sharon Hu; Jesús A. Izaguirre
Assistant Professors:
Surendar Chandra; Amitabh Chaudhary; Christian Poellabauer; Matthias Scheutz; Aaron Striegel; Douglas Thain
Professional Specialist:
Gregory R. Madey
Associate Professional Specialist:
Ramzi K. Bualuan; J. Curt Freeland
Assistant Research Professors:
Nitesh Chawla; Ashish Gehani; Michael Niemier

Program of Studies. The Department of Computer Science and Engineering offers programs of study that 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 PhD

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 quantitative 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 that 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 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 20211. Fundamentals of Computing I	4
CSE 20210. Discrete Mathematics	3
MATH 20550. Calculus III	3.5
PHYS 10320. General Physics II	4
Arts and Letters course +	3
	17.5

Second Semester

CSE 20212. Fundamentals of Computing II	4
CSE 20221. Logic Design	4
MATH 20580. Introduction to Linear Algebra and Differential Equations	3.5
Technical Elective	3
Arts and Letters course +	3
	17.5

Junior Year

First Semester

CSE 30331. Data Structures	3
CSE 30321. Computer Architecture I	4
EE 20224. Introduction to Electrical Engineering	4
Free Elective	3
Arts and Letters course +	3
	17

Second Semester

CSE 30322. Computer Architecture II	4
CSE 30341. Operating System Principles	3
EE 20234. Electric Circuits	3
MATH 30440. Probability and Statistics	3
Arts and Letters course +	3
	16

Senior Year

First Semester

EE 30344. Signals and Systems I	3
CSE Electives*	9
Free Elective	3
	15

Second Semester

CSE 40175. Ethics and Professional Issues	3
EE 20242. Electronics I	4
CSE Elective*	3
Arts and Letters course+	3
	13

Total Program Credits: 130

COMPUTER SCIENCE PROGRAM:

Sophomore Year

First Semester

CSE 20211. Fundamentals of Computing I	4
CSE 20210. Discrete Mathematics	3
MATH 20550. Calculus III	3.5
PHYS 10320. General Physics II	4
Arts and Letters course+	3
	17.5

Second Semester

CSE 20212. Fundamentals of Computing II	4
CSE 20221. Logic Design	4
MATH 20580. Introduction to Linear Algebra and Differential Equations	3.5
Technical Elective	3
Arts and Letters course+	3
	17.5

Junior Year

First Semester

CSE 30331. Data Structures	3
CSE 30321. Computer Architecture I	4
CSE Elective*	3
Technical Elective	3
Arts and Letters course +	3
	16

Second Semester

CSE 30351. Theory of Computing	3
CSE 30341. Operating System Principles	3
CSE Elective*	3
MATH 30440. Probability and Statistics	3
Arts and Letters course +	3
	15

Senior Year

First Semester

CSE 40113. Algorithms	3
CSE Electives*	6
Technical Elective	3
Free Elective	3
	15

Second Semester

CSE 40175. Ethics and Professional Issues	3
CSE Electives*	6
Arts and Letters course+	3
	12

Total Program Credits: 129

+ *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.

CSE 20033. Functional Programming

(3-0-3)

Prerequisite(s): CSE 20232 or CSE 232

The focus in this course is on the effective use of the computer in problem solving. The student will learn how to formulate data and procedural abstractions and deal with the complexities of large software systems. As a vehicle for handling this complexity, the functional programming language scheme will be used.

CSE 20110. Discrete Mathematics

(3-0-3) Chaudhary

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, and machine computation.

CSE 20211. Fundamentals of Computing I

(3-1-4) Striegel

Prerequisite(s): see online Course Catalog for details.

Corequisite(s): CSE 21211

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.

CSE 21211. Fund of Computing I Lab

(0-0-0)

Corequisite(s): CSE 20211

Lab for Fundamentals of Computing I.

CSE 20212. Fundamentals of Computing II

(3-1-4)

Prerequisite(s): CSE 20211 or CSE 211

Corequisite(s): CSE 21212

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, genericness, inheritance, subtyping, design patterns, testing, concurrency, object persistency, and databases.

CSE 20221. Logic Design and Sequential Circuits

(3-3-4)

Corequisite(s): CSE 21221

Boolean algebra and switching circuits, Karnaugh maps, design of combinational and of sequential logic networks, and sequential machines.

CSE 20232. Advanced Programming

(3-0-3)

Prerequisite(s): see online Course Catalog for details.

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.

CSE 20600. CSE Service Projects

(V-0-V) Brenner, Freeland, Madey, Spies

Engineering projects in community service.

CSE 21212. Fundamentals of Computing II Lab

(0-0-0)

Corequisite(s): CSE 20212

Lab Fundamentals of Computing II.

CSE 21221. Logic Design Laboratory

(0-0-0)

Corequisite(s): CSE 20221

Lab for Logic Design.

CSE 30151. Theory of Computing
(3-0-3)
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.

CSE 30246. 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 the implementation of a database system with a Web interface.

CSE 30321. Computer Architecture I
(3-3-4) Hu
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CSE 31321
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.

CSE 30322. Computer Architecture II
(3-3-4)
Prerequisite(s): see online Course Catalog for details.
A continuation of the architectural concepts in CSE 30321. 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.

CSE 30331. Data Structures
(3-0-3) Izaguirre
Prerequisite(s): see online Course Catalog for details.
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.

CSE 30341. Operating System Principles
(3-0-3)
Prerequisite(s): (CSE 30321 or 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.

CSE 30600. CSE Service Projects
(V-0-V) Brenner, Freeland, Madey, Spies
Engineering projects in community service.

CSE 31321. Computer Architecture I Lab.
(0-0-0)
Corequisite(s): CSE 30321
Lab for Computer Architecture I.

CSE 31322. Computer Architecture II Lab
(0-0-0)
Corequisite(s): CSE 30322
Lab for Computer Architecture II.

CSE 40075. Computer Vision
(3-0-3)
This course seeks to develop a solid foundation for reasoning about the difficult ethical, professional, and social controversies that arise in the computing field.

CSE 40091. Frontiers in Microelectronic Systems
(3-0-3)
Frontiers in Microelectronic Systems.

CSE 40113. Algorithms
(3-0-3) Chen
Prerequisite(s): (CSE 30331 or 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).

CSE 40131. Programming Languages
(3-0-3)
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.

CSE 40166. Computer Graphics
(3-0-3) Flynn
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.

CSE 40171. Introduction to Artificial Intelligence
(3-0-3) Scheutz
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.

CSE 40232. Software Engineering
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Software engineering is an engineering discipline that is concerned with all aspects of producing high-quality, cost-effective, and maintainable software systems. This course provides an introduction to the most important tasks of a software engineer: requirements engineering, software design, implementation and testing, documentation, and project management. A medium-scale design project combined with individual assignments complement the lectures.

CSE 40239. Computer Simulation
(3-0-3)
Prerequisite(s): (MATH 30530 or MATH 323)
Computer techniques for simulating the behavior of physical, biological, engineering, and social systems, including both natural and artificial systems. Applications include scientific enquiry, engineering design, manufacturing planning, training, entertainment, and games. Topics include animation, visualization, and graphical analysis of results.

CSE 40243. Compilers
(3-0-3)
Prerequisite(s): (CSE 30331 or CSE 331)
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.

CSE 40244. Introduction to Systems Administration
(3-0-3) Freeland
Prerequisite(s): (CSE 30341 or CSE 341)
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.

CSE 40258. Network Management
(3-0-3)
An introduction to the concepts and practices of computer network management, including network installation, monitoring, and troubleshooting.

CSE 40411. Automata
(3-0-3)
Prerequisite(s): (CSE 30331 or 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.

CSE 40422. Computer System Design
(3-0-3)
Prerequisite(s): (CSE 30322 or CSE 322)
Integrated hardware and software development, construction, and testing of digital systems by design teams to meet specifications subject to technical, economic, and environmental constraints.

CSE 40456. Data Networks
(3-0-3) Schafer
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.

CSE 40462. VLSI Circuit Design
(3-0-3) Brockman
Prerequisite(s): (CSE 20221 or CSE 221)
CMOS devices and circuits, scaling and design rules, floor planning, data and control flow, synchronization and timing. Individual design projects.

CSE 40463. Real Time Systems
(3-0-3) Poellabauer
This course introduces students to fundamental topics in the theory and application of real-time systems. Topics covered include basic concepts such as predictability, worst-case execution time analysis, fault tolerance, real-time communication and synchronization, and advanced topics such as real-time operating systems, embedded computing, real-time CORBA and Java, and power management.

The course will be project-oriented and the students have the opportunity to analyze the deficiencies of general-purpose operating systems for the use in real-time and embedded systems and they will implement and experiment with real-time extensions to an operating system kernel.

CSE 40531. Computational Biology
(3-0-3)
Computational Biology (this course is no longer taught)

CSE 40535. Special Studies: Computer Vision
(3-0-3)
An introduction to the major biometric techniques (fingerprint, face, iris, voice, hand shape), the underlying pattern recognition basis for these biometrics, and current concerns regarding privacy and social / ethical issues.

CSE 40539. Simulation of Complexity
(3-0-3)
Computer simulation of biosystems.

CSE 40567. Computer Security
(3-0-3)
Prerequisite(s): (CSE 30341 or CSE 341)
This course is a survey of topics in realm of computer security. This course will introduce the students to many contemporary topics in computer security ranging from PKIs (Public Key Infrastructures) to cyber-warfare to security ethics. Students will learn fundamental concepts of security that can be applied to many; traditional aspects of computer programming and computer systems design. The course will culminate in a research project where the student will have an opportunity to more fully investigate a topic related to the course.

CSE 40600. CSE Service Projects
(V-0-V) Brenner, Freeland, Madey, Spies
Engineering Projects in Community Service.

CSE 40611. Team Software Design and Implementation
(3-0-3)
This course builds on the basic techniques introduced in Fundamentals of Computing I and II but emphasizes a team approach to the design and implementation of software. A variety of team structures will be considered, including two-person teams for extreme programming and three-person reams as used in the ACM programming contest. Student teams will develop software to solve problems ranging across the computer science curriculum and will present their solutions to the class for critique and analysis. Students will participate in the fall campus programming contest and selected students will represent the University in the ACM Regional Programming Contest.

CSE 40613. Intro to e-Technology
(3-0-3)
Introduction to concepts, theories, and techniques of Internet and WWW programming. The goal of this course is to prepare the student to design and develop Web-based applications, e-Commerce applications, e-Science applications, and Internet-based services. Students will be expected to design a large system (course project) requiring integration with other student projects.

CSE 40655. Tech Concepts of Visual FX
(3-0-3)
Behind every Hollywood visual effects blockbuster and hit video game are countless software developers and engineers working creatively to develop new tools and techniques for producing cutting edge 3-D computer-generated artwork. In this class, students will be introduced to the technical concepts used in producing CG artwork for films or video games. They will learn what's involved, from a technical standpoint, in bringing a visual effect to life from script to screen. They will work in a simulated production environment to develop tools and techniques for such things as file asset management, advanced lighting and texturing techniques, render management and optimization, dynamics simulation, and digital compositing. Students are expected to be very self-motivated, and the class will rely on open discussions about approaches to problem-solving and tool development.

CSE 40656. Advanced Databases
(3-0-3)
Prerequisite(s): (CSE 30246 or CSE 346)
Advanced topics in databases. DBA techniques.

CSE 40721. Advanced Architecture
(3-0-3) Kogge
Prerequisite(s): see online Course Catalog for details.
Advanced topics in computer architecture.

CSE 40726. CAD of Digital Systems
(3-0-3)
This is a senior/entry-graduate-level course intended to expose students to the fundamentals of CAD tools for the design and analysis of digital systems. The course aims at introducing to students the theory and implementation behind commercial CAD tools so that the students will be able to contribute to the development of such tools as well as be productive users of such tools. The main topics include basic algorithms for CAD, digital system modeling, timing and power analysis, logic/architectural synthesis, physical level design, and system-level design.

CSE 40741. Digital Multimedia Hub System Design
(3-0-3)
Digital Multimedia Hub System Design (This course is no longer taught)

CSE 40743. Behavior-Based Robotics
(3-0-3)
This course is designed to provide a forum for applying and testing artificial intelligence methods and models, especially behavior-based techniques, on a robot. While models will be evaluated with respect to their theoretical tenability, most emphasis will be given to issues of practicality. These practical considerations will be extensively studied in simulations as well as real-world implementations on a variety of robots. Implementations might also comprise new ideas, with the goal of original research results.

CSE 40753. Digital Systems Testing
(3-0-3)
A comprehensive and detailed treatment of digital systems testing and testable design. Fundamental concepts as well as the latest advances and challenges in the field of ULSI/VLIS testing are examined. Topics covered include fault modeling and simulation, combinational and sequential circuit test generation, memory and delay test, and design-for-testability methods such as scan and built-in self-test. Testing of embedded cores in systems-on-chip environments is also considered. A major outcome of this course is the analysis, design, and implementation of CAD tools that give solutions to test-related problems.

CSE 40764. Computer Networks
(3-0-3)
This course introduces students to topics on the principles, design, implementation, and performance

of computer networks. Topics include Internet protocols and routing, congestion control, switching and routing, mobile IP and ad-hoc networks, network security, the end-to-end arguments, peer-to-peer systems, and other current research topics.

CSE 40771. Distributed Systems
(3-0-3)
A distributed system is a collection of independent machines that work together on a common problem. Distributed systems have been both interesting and difficult to build because their components may be autonomous and highly failure-prone. The primary material for this course will be a series of papers describing both working distributed systems and theoretical results. Topics may include distributed file and storage systems, batch computing, peer-to-peer computing, grid computing, process migration, fault tolerance, security, time and ordering, and distributed agreement. Students will undertake a course project that involves building and evaluating a distributed system. Grading will be based on discussion, exams, and the course project.

CSE 45605. Internship
(V-0-V)
Industry-based internship.

CSE 46191. Directed Readings-Biometrics
(3-0-3)
Directed readings in the field of biometrics.

CSE 47900. Special Studies
(V-0-V)
Prerequisite(s): (CSE 20212 or CSE 212)
Individual or small group study under the direction of a CSE faculty member in an undergraduate subject not currently covered by any University course.

CSE 48100. Capstone Research
(3-0-3)
A senior design experience incorporating scholarly research and development of systems, tools, and techniques to address a research question. Students will be presented with a problem domain and a research problem description, and will be required to perform problem analysis, identify a potential solution, place the solution in the context of existing work, implement a prototype of the solution, test and assess the prototype, document all steps, and present their work.

CSE 48900. Undergraduate Research
(V-0-V)
A research project at the undergraduate level under the supervision of a CSE faculty member.

CSE 48901. Undergraduate Research
(V-0-V)
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. Freimann 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; Christine M. Mazier; Alan C. Seabaugh; Gregory L. Snider; Robert L. Stevenson; John J. Uhran Jr.
Associate Professors:
Patrick J. Fay; Douglas C. Hall; Thomas H. Kosel; Ken D. Sauer
Assistant Professors:
Martin Haenggi; Debdeep Jena; John B. Kenney (adjunct); J. Nicholas Laneman; Paulo Tabuada; Haili (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

Statement of Goals and Objectives. The goals of the Department of Electrical Engineering's academic programs are to provide quality education and to 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 these goal are 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 image 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, microwave circuit/device characterization, and digital signal/image processing. 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 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 20550. Calculus III	3.5
PHYS 10320. General Physics II	4
CSE 20232. C/C++ Programming	3
EE 20224. Introduction to Electrical Engineering	4
Arts and Letters course+	3
	17.5

Second Semester

MATH 20580: Introduction to Linear Algebra and Differential Equations	3.5
PHYS 20330. General Physics III	3.5
EE 20242. Electronics I	4
EE 20234. Electric Circuits	3
CSE 20221. Logic Design	4
	18

Junior Year

First Semester

MATH 30650. Differential Equations	3
EE 30344. Signals and Systems I	3
EE 30347. Semiconductors I	3
EE 30348. Electromagnetic Fields and Waves I	3
Arts and Letters course+	3
	15

Second Semester

MATH 30530. Probability	3
Electrical Engineering Electives*	6
Technical Elective	3
Arts and Letters course+	3
	15

Senior Year

First Semester

EE 41430. Senior Design I	3
Electrical Engineering Electives*	6
Engineering Science Elective†	3
Arts and Letters course+	3
	15

Second Semester

EE 41440. 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 30342, 40446, 40455, 40458, and 40468.*

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

† The engineering science and technical elective course lists may be found on the Electrical Engineering website.

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.

EE 20224. Introduction to Electrical Engineering
(3-3-4) Tabuada
Corequisite(s): EE 21224
A project-oriented introduction to electrical engineering principles in which long-term projects are used to introduce such topics as node and loop circuit analysis, network theorems, first-order circuits, operational amplifiers, communications, systems theory, microprocessor interfacing techniques, and computer programming. Fall.

EE 20234. Electric Circuits
(3-0-3)
Prerequisite(s): (EE 20224 or EE 224)
Analysis of first, second, and higher order circuits, including natural response, forced response, phasor concepts, AC methods, frequency response, and Laplace transform techniques.

EE 20242. Electronics I
(3-3-4)
Prerequisite(s): (EE 20224 or EE 224)
Introduction to electronic circuits and systems. Basic diode and transistor circuits and the associated DC basic analysis and AC small signal analysis. Voltage and feedback amplifiers. Logic and analog circuits utilizing discrete solid-state devices. Spring.

EE 21224. Introduction to Electrical Engineering Lab
(0-0-0) *Corequisite(s)*: EE 20224
This lab supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 21242. Electronics I Lab
(0-0-0)
This lab supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 30342. Electronics II
(3-3-4)
Prerequisite(s): (EE 20242 or 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.

EE 30344. Signals and Systems I
(3-0-3) Haenggi
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.

EE 30347. Semiconductors I: Fundamentals
(3-0-3) Hall
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.

EE 30348. Electromagnetic Fields and Waves I: Fundamentals
(3-0-3) Jena
A basic course in electromagnetic field theory, using Maxwell's equations as the central theme. Vector analysis is employed extensively. Fall.

EE 30354. Signals and Systems II
(3-0-3)
Prerequisite(s): (EE 30344 or EE 344)
Corequisite(s): EE 32354
Linear systems analysis with emphasis on discrete time case; sampling theory, discrete Fourier transform, Z-transform, applications in signal processing, communications, and control. Spring.

EE 30357. Semiconductors II: Devices
(3-0-3)
Prerequisite(s): (EE 30347 or EE 347)
Corequisite(s): EE 32357
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.

EE 30358. Electromagnetic Fields and Waves II: Applications
(3-0-3)
Prerequisite(s): (EE 30348 or EE 348)
Corequisite(s): EE 32358
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.

EE 30372. Electric Machinery and Power Systems
(3-0-3)
Prerequisite(s): (EE 30348 or EE 348)
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.

EE 31342. Electronics II Lab
(0-0-0)
This lab supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 32344. Signals & Systems I Recitation
(0-0-0)
Recitation designed to help engineering students with their problem-solving skills in a smaller group setting.

EE 32347. Semiconductors I: Recitation
(0-0-0)
Recitation designed to help engineering students with their problem-solving skills in a smaller group setting.

EE 32348. Electromagnetic Fields and Waves I Recitation
(0-0-0)
Recitation designed to help engineering students with their problem solving skills in a smaller group setting.

EE 32354. Signals and Systems II Recitation
(0-0-0)
Corequisite(s): EE 30354
Recitation designed to help engineering students with their problem-solving skills in a smaller group setting.

EE 32357. Semiconductors II Recitation
(0-0-0)
Corequisite(s): EE 30357
Recitation designed to help engineering students with their problem-solving skills in a smaller group setting.

EE 32358. Electromagnet Fields and Waves II Recitation
(0-0-0)
Corequisite(s): EE 30358
Recitation designed to help engineering students with their problem-solving skills in a smaller group setting.

EE 40446. IC Fabrication Laboratory
(2-6-4) Snider
Corequisite(s): EE 41446
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 5000 transistor CMOS LSI circuit. Fall.

EE 40453. Communication Systems
(3-0-3) Fuja
Prerequisite(s): see online Course Catalog for details.
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.

EE 40455. Control Systems
(3-3-4) Antsaklis
Design of linear feedback control systems by state-variable methods and by classical root locus, Nyquist, Bode and Routh-Hurwitz methods. Fall.

EE 40456. Data Networks
(3-0-3) Schafer
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.

EE 40458. Microwave Circuit Design and Measurements Laboratory
(2-3-3) Fay
Prerequisite(s): (EE 30348 or EE 348)
Corequisite(s): EE 41458
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.

EE 40462. VLSI Circuit Design
(3-0-3) Brockman
CMOS devices and circuits, scaling and design rules, floor planning, data and control flow, synchronization, and timing. Individual design projects.

EE 40465. Space Systems and Analysis
(3-0-3)
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. Spring.

EE 40468. Modern Photonics Laboratory
(2-3-3)
Prerequisite(s): (EE 30347 or EE 347)
Corequisite(s): EE 41468
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.

EE 40471. Digital Signal Processing
(3-0-3)
Prerequisite(s): (EE 30354 or EE 354)
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.

EE 41430. Senior Design I
(1-6-3)
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.

EE 41440. Senior Design II
(0-9-3)
Prerequisite(s): (EE 41430 or EE 430)
The second part of a yearlong senior design project. In this part, students implement, test and document their senior project. Spring.

EE 41446. IC Fabrication Laboratory
(0-0-0)
Corequisite(s): EE 40446
This lab supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 41455. Control Systems Laboratory
(0-0-0)
This lab supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 41458. Microwave Circuit Design and Measurement Lab
(0-0-0)
Corequisite(s): EE 40458
This course supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 41468. Photonics Lab
(0-0-0)
This lab supplements the materials presented in the lecture setting and gives students the opportunity to reinforce their learning through hands-on experiments and through demonstrations in a laboratory environment.

EE 47000. Electric Vehicle Engineering
(3-0-3)
This course is an introduction to the engineering aspects of battery-operated electric vehicles. Emphasis is placed on the system dynamic aspects of the vehicle-track system and problems in electric vehicle racing. Other areas of concentration are modeling of the powertrain system, optimization, and vehicle simulation. Instructor approval required.

EE 47001. Frontiers in Microelectronic Systems
(3-0-3)
This capstone course of the bits-to-chips course sequence covers multidisciplinary aspects of integrated circuits design and fabrication. Emphasis is on interfaces between various aspects of architecture, design and fabrication. Students study technologies and issues in advanced IC manufacturing, and work on several projects including plans for an advanced IC for industry and an IC appropriate for fabrication at ND. Students fabricate ICs with tens of thousands of transistors from their own designs.

EE 47006. Circuits and Systems
(3-0-3)
Study of electrical circuits from the systems point of view. The intrinsic feedback features of electrical circuits. Extensions of the ideas of Thevenin and Norton. Principles of automatically generating circuit models and solutions. Essential electric and magnetic features of circuits. Qualitative features of electrical circuits.

EE 47498. Special Studies
(V V-V)
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

EE 48499. Undergraduate Research
(V-0-V)
A research project at the undergraduate level under the supervision of a faculty member.

EE 48999. Undergraduate Research
(V V-V)
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.

60550. Linear Systems
60551. Mathematical Programming
60553. Advanced Digital Communications
60554. Computer Communication Networks
60555. Multivariable Control Systems
60556. Fundamentals of Semiconductor Physics
60558. Microwave Circuit Design & Meas.
60561. Multi-Dimensional Signal Processing
60563. Random Variables and Stochastic Processes
60566. Solid State Devices
60568. Electromagnetic Theory I
60571. Statistical Signal Processing
60576. Microelectronic Materials
60580. Nonlinear Control Systems
60581. 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.

EG 00100. Introduction to Engineering
(3-3-0) Bualuan
This course is designed for rising high schools seniors who are interested in exploring engineering as a career. Included are lectures, field trips, and design projects reflecting what engineers do and how they do it. It is offered twice during the summer period.

EG 00200. Introduction to Engineering
(3-3-0) Bualuan
This course is designed for rising high schools seniors who are interested in exploring engineering as a career. Included are lectures, field trips, and design projects reflecting what engineers do and how they do it. It is offered twice during the summer period.

EG 10111. Introduction to Engineering Systems I
(3-0-3)
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. Structured programming is introduced, and computing skills are developed for engineering analysis, synthesis, and technical communication.

EG 10112. Introduction to Engineering Systems II
(3-0-3)
Prerequisite(s): see online Course Catalog for details. The second of a two-course sequence intended to continue the introduction of first-year intents to the engineering disciplines. Multidisciplinary 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 all departments of the College of Engineering. Structured programming and software skills are further developed.

EG 27200. EPICS: Engineering Projects in Community Service
(V-0-V)
A course that partners teams of students with local community service organizations. Projects involve strong technical content, significant design, and interdisciplinary effort and a strong communication component.

EG 37300. EPICS: Engineering Projects in Community Service
(V-0-V)
A course that partners teams of students with local community service organizations. Projects involve strong technical content, significant design, and interdisciplinary effort and a strong communication component.

EG 40298. Mastering Techniques for Excellence in Engineering Seminar
(2-0-2)
This course is designed to help students achieve a degree of proficiency in their studies by looking at various techniques to accomplish this goal. This very interactive class is supplemented with a variety of outside experts in these techniques.

EG 40421. Integrated Engineering and Business Fundamentals
(3-0-3) Dunn
The course is designed to improve the effectiveness of engineers working in corporations by teaching how and why businesses operate. Subjects covered include business financial reporting, business plans, 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.

EG 40422. Advanced Integrated Engineering and Business Topics
(3-0-3)
Prerequisite(s): see online Course Catalog for details. 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.

EG 45029. Internship
(1-0-1)
Students are required to combine three areas of knowledge and experience, then present them in an academic format, following a summer internship opportunity. This course is designed for international undergraduate students in the College of Engineering who have secured an internship opportunity congruent with their respective majors. Students must meet with the program coordinator before starting the internship. (Credit does not apply toward graduation.)

EG 45498. Research Experience—Undergraduate
(0-0-0)
This is a research course for students involved in a Research for Undergraduates (REU) program sponsored by the NSF. It takes place under a faculty member in any of the departments in the college and has a duration of eight to 12 weeks. Offered each summer.

EG 47198. Integrated Engineering and Business Fundamentals
(3-0-3)
The course is designed to improve the effectiveness of engineers working 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.

EG 47400. EPICS: Engineering Projects in Community Service
(V-0-V)
A course that partners teams of students with local community service organizations. Projects involve strong technical content, significant design, and interdisciplinary effort and a strong communication component.

EG 47998. Heat Transfer
(3-0-3)
An introductory course covering three modes of heat transfer: steady and unsteady conduction, elementary boundary layer analysis for malinar and turbulent convection, and the basic theory of radiation. Spring.

ESTS 40401. Energy and Society: Options and Challenges
(3-0-3) Incropera
This three-credit course provides a comprehensive treatment of the role of energy in society and may be taken concurrently by engineering and non-engineering students. It proceeds along two parallel tracks, one dealing with the scientific/technical foundations of energy utilization and the other with its economic, political, environmental, and ethical implications. Scientific/technical issues will be treated at a level that is appropriate for non-engineers and at the same time beneficial to both engineers and non-engineers. The required background in mathematics is largely confined to high school algebra, with occasional use of elementary concepts from differential and integral calculus.

ESTS 40402. Wireless Communications: The Technology and Impact of 24/7 Connectively
(3-0-3) Huang, Costello
This survey-style course offers an opportunity to gain a basic understanding of the technical, regulatory, and business aspects of the wireless revolution and its impact on society. It is intended for both engineering and non-engineering students. The course will include such topics as the representation, transmission, and reception of information in electrical form; the physical properties of radio signals and other wireless media; the principles and challenges of sharing a common medium; and privacy and security issues, as well as the social and commercial implications of wireless communications.

Dual Degree Programs

DUAL DEGREE PROGRAM WITH THE COLLEGE OF ARTS AND LETTERS

Coordinators:
John J. Uhran Jr.
Sr. 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 the sophomore year, 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 10550, 10560)	8
Natural Science (CHEM 10121, 10122)	7
	39

Arts and Letters Requirements

CSEM 23101	3
Literature or Fine Arts*	3
History or Social Science	3
Language**	6/9
Major (minimum)	27
	42/45

Engineering Requirements

MATH 20550, 20580	7
PHYS 10310, 10320	8
EG 10111, 10112	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 13100. Composition	3
History/Social Science*	3
MATH 10550. Calculus I	4
CHEM 10121. General Chemistry: Fundamental Principles	4
EG 10111. Introduction to Engineering Systems I	3
Physical Education	—
	17

Second Semester

University Seminar+	3
PHYS 10310. General Physics I	4
MATH 10560. Calculus II	4
CHEM 10122. General Chemistry: Biological Processes	3
EG 10112. Introduction to Engineering Systems II	3
Physical Education	—
	17

Third Semester

Theology/Philosophy	3
Modern Language	3
PHYS 10320. General Physics II	4
MATH 20550. Calculus III	3.5
Engineering Program†	3
	16.5

Fourth Semester

Theology/Philosophy	3
CSEM 23101. College Seminar	3
Modern Language	3
MATH 20580. 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:

Mary Goss
Director of Admissions
Master of Business Administration Program

John J. Uhran Jr.
Senior 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 MBA/engineering program should apply to the MBA 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/MBA program continues in the undergraduate engineering program and completes his or her undergraduate engineering program in the usual four-year time frame.

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:

Summer Session Following Junior Year	
Arts and Letters course+	3
Arts and Letters course+	3
Math Review Workshop*	0
Acc't Review Workshop*	0

Senior Year

First Semester	
ACCT 60000, Financial Accounting	2
MBET 60340. Conceptual Foundation of Business Ethics	2
MGT 60100. Statistics	2
MGT 60300. Organizational Behavior	2
Communications Seminar++	1
ACCT 60200. Cost Accounting	2
FIN 60400. Finance I	2
FIN 60210. Microeconomic Analysis	2
MARK 60100. Marketing Management	2
Engineering course	3**
	20

Second Semester	
FIN 70600. Finance II	2
FIN 60220. Macroeconomic Analysis	2
MGT 60900. Strategic Decision Making	2
Decision Making Seminar++	1
Seminar ++	1
Leadership	2
MGT 60700. Operations Management	2
Engineering courses	6
	20

Fifth Year

First Semester	
MGT 60200. Problem Solving	2
Management Comm Elective	2
Free MBA Elective	2
Special Case Studies Seminar++	2
Ethics elective	2
Management Comm elective	2
Engineering courses	6
	18

Second Semester	
MBA electives	4
Corporate Case Studies Seminar++	2
MBA electives	4
Engineering courses	6
	16

+See "Arts and Letters Core" on the first page of the College of Engineering section.
++Special one/two-week courses. All other MBA courses are seven weeks in length.
**Occurs during August Orientation*

Total for both degrees: 126–132 undergraduate, 48 MBA

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

Officers of Administration

FRANK P. INCROPERA, PhD
Matthew H. McCloskey Dean of the College of Engineering

JOHN J. UHRAN JR., PhD
Senior Associate Dean of the College of Engineering

PETER M. KOGGE, PhD
Associate Dean of the College of Engineering

STEPHEN E. SILLIMAN, PhD
Associate Dean of the College of Engineering

ROBERT J. CUNNINGHAM, BSEE, MBA
Director of Budget and Operations

STEPHEN M. BATILL, PhD
Chair of the Department of Aerospace and Mechanical Engineering

MARK J. McCREADY, PhD
Chair of the Department of Chemical and Biomolecular Engineering

PETER C. BURNS, PhD
Chair of the Department of Civil Engineering and Geological Sciences

KEVIN W. BOWYER
Chair of the Department of Computer Science and Engineering

YIH-FANG HUANG, PhD
Chair of the Department of Electrical Engineering

Advisory Council

QUINCY L. ALLEN
Rochester, New York

QUINCY JAMES P. BRADLEY
Dallas, Texas

PATRICK J. BRENNAN
Towson, Maryland

WENDELL F. BEUCHE
Chicago, Illinois

GREGORY BROWN
Schaumburg, Illinois

THOMAS DEGNAN JR.
Moorestown, New Jersey

GERALD G. DEHNER
Fort Wayne, Indiana

LUINO DELL'OSSO JR.
Mercer Island, Washington

LEO A. DILLING
Potomac, Maryland

WILLIAM E. DOTTERWEICH
Fort Wayne, Indiana

DENNIS O. DOUGHTY
McLean, Virginia

GEORGE R. DUNN
Kensington, Maryland

ANTHONY F. EARLEY JR.
Detroit, Michigan

FRANKLIN E. ECK
Columbus, Ohio

EDWARD B. FITZPATRICK JR.
Mineola, New York

CELESTE VOLZ FORD
Portola Valley, California

DONALD L. GOTHARD
Washington, Michigan

VICNENT N. GREGGO
Wilmington, Delaware

THOMAS J. HESSERT
Haddonfield, New Jersey

SUZANNE M. HULL
New Canaan, Connecticut

JAMES H. HUNT JR.
McLean, Virginia

JOSEPH W. KEATING
Short Hills, New Jersey

JOHN M. KELLY JR.
Houston, Texas

CHARLES B. KITZ
West Bloomfield, Michigan

WILLIAM D. KLEINE
Midland, Texas

RICHARD E. LYON JR.
Chatham, New Jersey

DENNIS M. MALLOY
Houston, Texas

JOHN A. MARTELL
Granger, Indiana

REX MARTIN
Elkhart, Indiana

MARTIN A. MATICH
San Bernardino, California

LEO J. McKERNAN
South Bend, Indiana

CHARLES R. McNAMEE
Dayton, Ohio

WILLIAM D. MENSCH JR.
Mesa, Arizona

RAYMOND D. MEYO
Fairlawn, Ohio

DENNIS F. MURPHY
Omaha, Nebraska

JOSEPH B. NEUHOFF
Dallas, Texas

MYRON C. NOBLE
South Bend, Indiana

FRANK E. O'BRIEN JR.
Albany, New York

EDWARD M. O'TOOLE
Chicago, Illinois

H. EDWARD PREIN
Grand Rapids, Michigan

ROGER R. REGELBRUGGE
Charlotte, North Carolina

HARRY REICH
Trussville, Alabama

JOHN D. REMICK
Rochester, Minnesota

THOMAS M. ROHRS
Los Altos, California

WILLIAM G. ROTH
Marco Island, Florida

HUBERT J. SCHLAFLY
Greenwich, Connecticut

SEDRA M. SPRUELL
Missouri City, Texas

KENNETH E. STINSON
Omaha, Nebraska

JOHN A. TESKE
Palos Verdes Estates, California

SHAWN T. TILSON
Burlington, Ontario, Canada

JAMES D. TOOLE
Tucson, Arizona

PATRICK A. TOOLE
Westport, Connecticut

JOSEPH TRUSTEY
Wenham, Massachusetts

LAVETTA C. WILLIS
Los Angeles, California

RICHARD P. WOLSFELD
Minneapolis, Minnesota

DONALD J. ZEIER
McCook, Illinois