College of Engineering
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 the departments of aerospace and mechanical engineering, chemical engineering, civil engineering and geological sciences, computer science and engineering, and electrical engineering.

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

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 the young engineer need not acquire registration immediately upon graduation, he or she benefits 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.

Programs and Degrees

The College of Engineering offers curricula leading to the degrees listed below:
- B.S. in aerospace engineering
- B.S. in chemical engineering
- B.S. in civil engineering
- B.S. in computer engineering
- B.S. in electrical engineering
- B.S. in environmental geosciences
- B.S. in mechanical engineering
- B.S. in computer science

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

To obtain two undergraduate degrees from the College of Engineering, a student must successfully carry out an approved program of courses totaling at least 165 credit hours. These must include all of the courses specified in the Bulletin for each degree.

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

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

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

Engineering Common Core. All engineering curricula consist of each of the following:
- Arts and Letters 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).
- Basic Science Core: 36 credit hours. MATH 125: Calculus I, MATH 126: Calculus II, MATH 225: Calculus III, MATH 228: Introduction to Linear Algebra and Differential Equations, CHEM 117: General Chemistry I, CHEM 116: General Chemistry II, PHYS 131: General Physics I, PHYS 132: General Physics II, EG 111, 112: Introduction to Engineering Systems I and II

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

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

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

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

First Semester
- Composition or University Seminar* 3
- MATH 125: Calculus I 4
- CHEM 117: General Chemistry I 4
- Arts and Letters course* 3
- EG 111: Introduction to Engineering Systems I 3
- Physical Education

Second Semester
- University Seminar* or Composition 3
- MATH 126: Calculus II 4
- CHEM 116: General Chemistry II 3
- PHYS 131: General Physics I 4
- EG 112: Introduction to Engineering Systems II 3
- Physical Education

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

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

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

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

International Study Opportunities. The University strongly supports study abroad and has encouraged the programs in the College of Engineering to participate. At present, there is a summer program in London for any engineering student and a program during the fall semester of junior year in London for aerospace and mechanical engineering students (see page 240), civil engineering students (see page 248), computer science and computer engineering students (see page 253) and electrical engineering students (see page 257). There is also a fall-semester junior-year program in Perth, Australia, for civil engineering and environmental geoscience students (see page 248). Currently, other engineering programs are planning semester studies abroad as well. With special permission, most College of Engineering students can also arrange a semester in Monterrey, Mexico, or a year in Dublin.

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. Not more than three credits may be substituted for history or social science. All air, military or naval science credits not so substituted are not credited toward degree requirements in programs in the College of Engineering.

Women in Engineering. Engineers apply mathematics, science and technology to utilize the materials and forces of nature for better living. They are designers, thinkers and planners, and 90 percent of them work at a desk or in a laboratory. The environment of the job, the work to be done and the rewards are as agreeable to a woman as to a man. Today's engineering student receives a broad, liberal education designed to increase his or her awareness of the world and to influence some contribution toward its improvement.

To a woman, engineering offers equal opportunity and equal pay with a choice of specialties and jobs, so that natural talents and acquired skills can be used to the maximum. Women have demonstrated their ability to perform very well as engineers.

The demand for women engineers is currently very strong, and there is every indication that the doors will be wide open for many years, until the proportion of women in engineering becomes more nearly equal to their proportion in the total population.

Humanities in the Engineering 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 his or her 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 in the Corporate Environment. The college recognizes the importance of providing its graduates with opportunities to learn how engineers function in the world of business, and several departments 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 corporate 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 corporate 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 five-year programs combining the basic stem of the liberal arts program with the technical requirements of the various engineering programs. The student completing one of these combination programs 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 on pages 284-285 of this Bulletin.

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

The program is structured so that a student who has completed the first three years of the bachelor's degree program, if accepted, completes the master of business administration and the bachelor of science in a summer session and two subsequent academic years.
Students who wish to pursue this program should have a superior scholastic record in their undergraduate program and must make application to, and be accepted by, the M.B.A. program.

The general sequence of courses in the five-year engineering-M.B.A. program may be found on pages 284-285 of this 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 his or her college of first choice and two years at Notre Dame. After completion of the program, he or she 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, mechanics, theology, philosophy, history, social science and literature or fine arts is at least equivalent to that in the Notre Dame program.

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 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.

The Scope of the Graduate Program. Extensive graduate work in engineering is comparatively recent. Prior to World War II, the demand for engineers versed in the higher branches of the sciences was relatively small and was met by attracting physicists and mathematicians with graduate training into the field of engineering. 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.

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

College Awards and Prizes

College of Engineering Award

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

Departmental Awards

Aerospace and Mechanical Engineering

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

Vincent P. Goddard Design Award. Presented each year to a senior in aerospace engineering for the most diligence and persistence in the pursuit of undergraduate studies in aerospace engineering.

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

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

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

AND GEOLOGICAL SCIENCES

CIVIL ENGINEERING

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

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

CHEMICAL ENGINEERING

ACSE 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 Engineering.

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

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

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

CIVIL ENGINEERING AND GEOLOGICAL SCIENCES

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

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

COMPUTER SCIENCE AND ENGINEERING

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

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

ELECTRICAL ENGINEERING

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

The James L. Measor 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 Lawrence 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. Presented to a student through hard work and dedication to obtaining the best possible education.

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

The Kenneth R. Lauer Award.

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

The Sydney Kelsey Outstanding Scholar Award. For achievement in electrical engineering, recalling circuit theory, the English language, and St. George Day at Notre Dame.

The Arthur J. Quigley Award. For achievement in electrical engineering, recalling communication theory, undergraduate teaching, and the Binary Examination.

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The Kenneth R. Lauer Award.

THE NOTRE DAME TECHNICAL REVIEW

Student Organizations and Activities

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 attainments as alumni in the field of engineering. Seniors and juniors in the top fifth and top eighth of their respective classes are eligible for election under rigid standards of scholarship, character, leadership and service.

ETA KAPPA NU

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

PI TAU SIGMA

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

CHI EPSILON

The Notre Dame Chapter of Chi Epsilon, the national honor society for civil engineers, was installed at Notre Dame in 1966. The purpose of Chi Epsilon is to give recognition to those civil engineering students, faculty and alumni who have displayed superior qualities in scholarship, character, practicality and sociability during their professional careers.
SIGMA GAMMA TAU
The Notre Dame Chapter of the national honor society for Aerospace Engineering was installed in 1981. This organization recognizes and honors those individuals in the field of aeronautics and astronautics who have distinguished themselves through scholarship, integrity, service and outstanding achievement. Senior students who rank in the top third of their aerospace engineering class are eligible for admission.

PROFESSIONAL SOCIETIES
The several departments of the college actively support student chapters of their respective professional societies; these are:
- The American Institute of Chemical Engineers
- The American Society of Civil Engineers
- The American Society of Mechanical Engineers
- The American Institute of Aeronautics and Astronautics
- The Institute of Electrical and Electronic Engineers
- The Society of Women Engineers
- The Society of Black Engineers
- The Society of Hispanic Engineers

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

Programs of Study

Aerospace and Mechanical Engineering

Chair:
Stephen M. Batill

Associate Chair:
Rodney L. McClain; Richard B. Strebinger

Niebur; Ryan K. Roeder

Clark Professor:
Hafiz M. Ariasi

Associate Professors:
John Koenigshof

Professors:
John E. Renaud; Mihir Sen; Steven B. Skaar; Samuel Paolucci; Francis H. Raven (emeritus); Kwang-tzu Yang (emeritus)

Associate Professors:
Edmundo Corona; Robert A. Howland; John W. Lucey; James J. Mason; Joseph M. Powers; Steven R. Schmid; Michael M. Stanisic

Assistant Professors:
Alan P. Bowling; J. William Goodwine Jr.; James E. Houghton (emeritus); Glen L. Niebur; Ryan K. Roeder

Associate Professional Specialist:
Rodney L. McClain; Richard B. Streibinger

Assistant Professional Specialist:
John Koenigshof

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

London Program. Students majoring in aerospace engineering and mechanical engineering may elect to spend the fall semester of their junior year in London. During their semester in London, students take courses offered by Notre Dame and British professors at Notre Dame’s London Centre near Trafalgar Square. The courses students take are Notre Dame courses, and credits earned are Notre Dame credits. The students take two or three technical courses and humanities elective courses so that they graduate with their class in the normal four years. Students participating in this program live as a group in residential facilities with supervision provided by the University. The semester enables students to combine their engineering studies with an opportunity to live and travel in Britain. Detailed information on this program can be obtained from the department office in 365 Fitzpatrick Hall, Notre Dame, IN 46556. Telephone (574) 631-5433, fax (574) 631-8341.

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 in the aerospace industry and research laboratories or for postbaccalaureate study in engineering, business or law. 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 on such integrating disciplines as design, experimental methods and systems analysis. Technical electives in the junior and senior year enable students to emphasize specific technical areas, including fluid mechanics and aerodynamics, thermal sciences, structures, materials, space sciences, experimental aerodynamics, applied mathematics and manufacturing.

The aerospace engineering program uses laboratories in Fitzpatrick Hall of Engineering and in the Hessert Center for Aerospace Research. The Hessert Center laboratories contain superior facilities for instruction and research. The facilities under graduates use include subsonic and supersonic wind tunnels, static and dynamic force and moment determination equipment, computer data acquisition systems, laser doppler and hotwire anemometry, flight simulation, optical particle sizing systems and a modern image analysis laboratory.
In addition to laboratory experience, the student also gains computational experience, since the program requires the use of computers in all courses. Computer equipment is available and the University’s Computing Center, the College of Engineering and the departmental laboratories. These facilities are available for use by students to complete required course work and research.

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

Further details about the standard aerospace program, the aerospace London Program and electives can be found on the World Wide Web at www.nd.edu/~ame.

**First Year of Studies**
First-year students intending to major in aerospace engineering when they become sophomores will find first-year course requirements on page 260.

**Sophomore Year**

<table>
<thead>
<tr>
<th>First Semester</th>
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<tbody>
<tr>
<td>MATH 225: Calculus III</td>
<td>3.5</td>
</tr>
<tr>
<td>PHYS 132: General Physics II</td>
<td>4</td>
</tr>
<tr>
<td>AME* 225: Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>AME 240: Introduction to Aeronautics</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.5</strong></td>
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<table>
<thead>
<tr>
<th>Second Semester</th>
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</thead>
<tbody>
<tr>
<td>MATH 228: Introduction to Linear Algebra and Differential Equations</td>
<td>3.5</td>
</tr>
<tr>
<td>AME 226: Mechanics II</td>
<td>3</td>
</tr>
<tr>
<td>AME/CE 238: Mechanics of Solids</td>
<td>4</td>
</tr>
<tr>
<td>AME 250: Techniques of Measurements and Data Analysis</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.5</strong></td>
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**Junior Year**

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<tr>
<th>First Semester</th>
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</thead>
<tbody>
<tr>
<td>AME 301: Differential Equations, Modeling and Control I</td>
<td>3</td>
</tr>
<tr>
<td>AME 350: Aerodynamics I</td>
<td>3</td>
</tr>
<tr>
<td>AME 372: Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>AME 360: Aerodynamics II</td>
<td>3</td>
</tr>
<tr>
<td>AME 346: Aerospace Structures</td>
<td>3</td>
</tr>
<tr>
<td>AME 342: Aerodynamics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>AME 355: Aerospace Measurement System Design</td>
<td>3</td>
</tr>
<tr>
<td>Technical Elective</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
</tr>
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</table>

**Senior Year**

<table>
<thead>
<tr>
<th>First Semester</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>AME 440: Flight Mechanics/Design</td>
<td>3</td>
</tr>
<tr>
<td>AME 443: Aerospace Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>AME 454: Aerospace Propulsion</td>
<td>3</td>
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<tr>
<td>Technical Elective</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AME 439: Heat Transfer</td>
<td>3</td>
</tr>
<tr>
<td>AME 441: Aerospace Design</td>
<td>4</td>
</tr>
<tr>
<td>AME 366 Orbital and Space Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>Technical Elective</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

Total for the four years: 129 semester hours.

* AME: Aerospace and Mechanical Engineering course

\[\text{See Arts and Letters core on page 260.}\]

\[\text{§ A list of approved aerospace engineering and general technical electives is available in the department.}\]

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 baccalaureate level which is designed to prepare the student for entrance into a professional career in a field of mechanical engineering or for post-baccalaureate study in engineering, medicine, law or business. The curriculum is based 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 design, manufacturing, mechanical systems, solid mechanics, robotics, thermodynamics, energy, and engineering business practice courses.

Laboratory experience in the program enables the student to correlate theoretical background with experimental studies. The design content of the curriculum provides an experience in which the student is able to integrate and apply the knowledge assimilated in the basic sciences, engineering sciences, social sciences and humanities to realistic and relevant problems. The design process is integrated at all levels of the curriculum, including five courses that are directed primarily toward design, and is culminated by a required senior-year comprehensive design experience."

To prepare for today’s changing technological world, the program requires a continual use of the computer in all of its courses. Students have access to computing facilities in the University’s Computing Center, the college’s independent computer facilities and the department’s own mini- and microcomputers. Wherever practicable, embeddable microprocessors are introduced into laboratory and design experiences.

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

Further details about the mechanical engineering program, the London Program and electives can be found on the World Wide Web at www.nd.edu/~ame. These details include the program of study requirements for graduating classes prior to the Class of 2005; the program below pertains only to the Class of 2005 and beyond.

**First Year of Studies**
First-year students intending to major in mechanical engineering when they become sophomores will find first-year course requirements on page 260.

**Sophomore Year**

<table>
<thead>
<tr>
<th>First Semester</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 225: Calculus III</td>
<td>3.5</td>
</tr>
<tr>
<td>PHYS 132: General Physics II</td>
<td>4</td>
</tr>
<tr>
<td>AME* 225: Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>AME 230: Introduction to Mechanical Engineering</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.5</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 228: Introduction to Linear Algebra and Differential Equations</td>
<td>3.5</td>
</tr>
<tr>
<td>AME 226: Mechanics II</td>
<td>3</td>
</tr>
<tr>
<td>AME 250: Techniques of Measurements and Data Analysis</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.5</strong></td>
</tr>
</tbody>
</table>

**Junior Year**

<table>
<thead>
<tr>
<th>First Semester</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AME 301: Differential Equations, Modeling and Control I</td>
<td>3</td>
</tr>
<tr>
<td>AME 350: Aerodynamics I</td>
<td>3</td>
</tr>
<tr>
<td>AME 372: Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td>Arts and Letters course*</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AME 360: Aerodynamics II</td>
<td>3</td>
</tr>
<tr>
<td>AME 346: Aerospace Structures</td>
<td>3</td>
</tr>
<tr>
<td>AME 342: Aerodynamics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>AME 355: Aerospace Measurement System Design</td>
<td>3</td>
</tr>
<tr>
<td>Technical Elective</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>
Senior Year

First Semester

CHEG* 225: Materials Science  3
AME Elective‡/AME 439: Heat Transfer  3
AME 339 Kinematics/Dynamics  3
Technical Elective‡  3
Arts and Letters course  3
Total  15

Second Semester

AME 470** Senior Design Project  4
AME 439: Heat Transfer/AME Elective  3
AME Elective‡  3
Technical Elective‡  3
Arts and Letters course  3
Total  16

* CHEG: Chemical Engineering course
* EE: Electrical Engineering course
* AME: Aerospace and Mechanical Engineering course
** Alternatively, Senior Design may be taken in the fall.
† A list of approved AME and general technical electives is available in the department.

Total for the four years: 129 semester hours.

AEROSPACE AND MECHANICAL 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.

225. Mechanics I
(3-0-3) Staff
Prerequisites: MATH 126, PHYS 131, EG 111 or equivalent.
Corequisite: MATH 225.
Introduction to systems of forces and couples. Equilibrium of particles, rigid bodies, systems. Internal forces and moments, distributed forces, friction, virtual work. Fall and spring.

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

236. Mechanics of Solids
(3-0-3) Staff
Prerequisites: AME 225, MATH 225.
An introduction to the mechanics of deformable solids. Concepts in stress, strain, stability and deformation of simple structures are introduced. Spring. (Note: AME 236 will be taught for the last time in spring 2002.)

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

241. CAD/CAM
(1-4-3) Staff
Introduction to computer aided design (CAD) and manufacturing (CAM). Principles of engineering graphic communication: 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. (Note: AME 241 will be taught for the last time in fall 2002.)

250. Techniques of Measurements and Data Analysis
(1-2-2) Staff
Introduction to experimental methods used in aerospace and mechanical engineering, including basic instrumentation, data acquisition and data analysis techniques. Embeddable microprocessors may be used for data acquisition and/or control. Spring.

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

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

302. Modeling and Control II
(3-1-3) Staff
Systems of nth-order differential equations, mechanical vibrations, linear feedback s-plane control analysis, frequency response analysis, partial differential equations.

321. Differential Equations and Applied Mathematics
(3-0-3) Staff
Prerequisite: MATH 228.
Ordinary and partial differential equations, Fourier series, initial and boundary value problems, linear algebra and transformation techniques as applicable to engineering problems.

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

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

331. Mechanics of Solids Laboratory
(1-2-2) Staff
Prerequisites: AME 250, AME/CE 236. Experimental study of solid mechanics. Fall. (Note: AME 331 will be taught for the last time in fall 2002.)

332. Fluid Mechanics Laboratory
(1-2-2) Staff
Prerequisites: MATH 334, AME 250. Experimental study of fluid mechanics. Spring. (Note: AME 332 will be taught for the last time in spring 2003.)

334. Fluid Mechanics
(3-0-3) Staff
Prerequisites: AME 226, MATH 228.
A basic course in fluid mechanics. Topics include fluid properties, hydrostatics, conservation laws, dimensional analysis, internal and external flows. Student and/or instructor-conducted experiments may entail use of embeddable microprocessors. Fall.
335. Intermediate Dynamics
(3-0-3) Howland, Huang
Prerequisites: AME 226, MATH 228.
Kinematics and dynamics of rigid bodies in three dimensions, Lagrange’s equations and linear vibrations. Fall.

339. Kinematics and Dynamics of Machines
(3-0-3) Stasnic
Prerequisites: AME 226, MATH 228.
Kinematic and dynamic analysis and synthesis of machinery with design applications. Fall.

340. Mechanical Engineering Design
(3-0-3) Staff
Prerequisites: AME/CE 236.
Static and fatigue failure theories. Theory, design and selection of gearing, power transmitting shafts, rolling element bearings, journal bearings, fasteners, springs, brakes and clutches. Spring.

341. Computer-Aided Design and Manufacturing
(1-4-5) F. Thomas, Nelson
Prerequisite: AME 250.
Corequisite: AME 360.
Use and operation of subsonic and supersonic wind tunnels, flow velocity, pressure and strain gauge measurements, data acquisition and analysis, with emphasis on interpretation of aerodynamic flow phenomena. Spring.

342. Aerodynamics Laboratory
(1-4-5) F. Thomas, Nelson
Prerequisite: AME 250.
Use and operation of subsonic and supersonic wind tunnels, flow velocity, pressure and strain gauge measurements, data acquisition and analysis, with emphasis on interpretation of aerodynamic flow phenomena. Spring.

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

345. Modeling and Analysis in Mechanical Engineering Design
(3-0-5) Staff
Modeling and analysis of mechanical systems. Automated design decision process, introduction to statistical methods, material engineering, requirements definition and product specifications.

346. Aerospace Structures
(3-0-3) Staff
Prerequisite: AME/CE 236.
Study of the basic principles and methods of structural analysis of lightweight structures. Introduction to stress, deformation, yielding, buckling, and fatigue/fracture analysis of truss and semi-monocoque structures, and mechanical behavior of aerospace structural methods. Fall.

348. Introduction to Nuclear Engineering
(3-0-3) Lucey
An introduction to the various areas within nuclear engineering. Attention is paid specifically to the application of nuclear-related phenomena to the practice of engineering. Fall.

350. Aerodynamics I
(3-0-3) Staff
Prerequisite: AME 240.
An intermediate course on the study of aerodynamics. Primary emphasis is placed on the development of two-dimensional airfoil and finite-wing theories. An introduction to boundary layers is also included. Spring.

355. Aerospace Measurement Systems Design
(3-0-3) P. Dunn
Individual and team-based design, fabrication, calibration, and implementation of on-board measurement systems for remote data acquisition. Emphasis is placed on developing a sensor/microprocessor/memory system that will be used in the subsequent senior aerospace design project. Spring.

360. Aerodynamics II
(3-0-3) Staff
Prerequisite: AME 350 or AME 334, or AME 327.
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.

366. Orbital and Space Dynamics
(3-0-3) Howland
Prerequisite: AME 226.

370. Manufacturing and Assembly for Aerospace Systems
(3-0-3) Renaud, Barill
Prerequisite: AME 225.
An introduction to processes and techniques associated with the component manufacturing and assembly for lightweight structures. Issues related to material processing, assembly, CAD and CAM as well as additional topics in manufacturing such as rapid prototyping, tolerancing and quality will be emphasized. Spring.

425. Vibrations
(3-0-3) Howland, Skaar
Prerequisite: MATH 325, AME 226.
Free, steady and transient response of linear single and multiple degrees of freedom systems. Various damping, dry friction damping, energy methods and numerical techniques. Fall.

430. Road Vehicle Dynamics
(3-0-3) Staff
Prerequisite: AME 226.
Introduction to the operation of vehicle subsystems such as transmissions, engines, brakes, suspensions, etc. Calculation and simulation of vehicle performance, handling and comfort. Discussion of industry technical standards, vehicle safety, restraint systems and federal safety standards. Not every year.

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

437. Control Systems Engineering
Prerequisites: MATH 325, AME 226.
(3-0-3) Goodwine
Application of modeling, feedback analysis and design to mechanical, thermal, electrical and fluid systems, including classical control theory in the frequency and time domains. Stability, performance and methods based on root-locus, Bode and Nyquist diagrams. Representation in state space and basic state space design. Spring.

438. Intermediate Fluid Mechanics
(3-0-3) Staff
Prerequisite: AME 334 or AME 360.
A second course in fluid mechanics, including potential flow, viscous flow, thermal convection, compressible flow and advanced topics. Fall.

439. Heat Transfer
(3-0-3) Staff
Prerequisites: AME 327, AME 334 or AME 350.
An introductory course covering three modes of heat transfer: steady and unsteady conduction, elementary boundary layer analysis for laminar and turbulent convection and the basic theory of radiation. Spring.

440. Flight Mechanics and Introduction to Design
(3-0-3) Staff
Prerequisite: AME 350.
The fundamentals of flight performance are developed. Primary emphasis will be on examining how configuration design parameters affect aircraft performance. Students are introduced to aircraft preliminary design methodology. Fall.

441. Aerospace Design
(2-4-4) Barill
Prerequisite: AME 440.
Team design project with application to an aerospace system development. Includes topics in all associated technologies, design methodology, standards and engineering ethics. Spring.
442. Mechanical Behavior of Materials
(3-0-3) Staff
Prerequisite: AME/CE 236, CHEG 225.
Mechanics of deformation and fracture of solids including metals, polymers, composites, ceramics and glass. Physical significance and limitations of the most important mechanical properties. Mechanical testing procedures. Correlation of the bulk engineering properties with the atomic-scale mechanisms. Not every year.

443. Aerospace Dynamics
(3-0-3) Nelson
Prerequisite: AME 226, AME 437.
Mechanics and equations of motion. Aerodynamics forces and motions, longitudinal, lateral and roll motions. Introduction to autopilot design. Fall.

444. Optimum Design of Mechanical Elements
(3-0-3) Renaud
Prerequisite: MATH 325.
Introduction to basic optimization techniques for mechanical design problems. Current applications. Spring.

445. Intermediate Heat Transfer
(3-0-3) Staff
Prerequisite: AME 439.
Fundamentals of heat convection and radiation, scalings and heat transfer analysis in external and internal flows, turbulent heat transfer, thermal radiation properties of ideal and real surfaces, radiative transfer with participating media. Spring.

446. Finite Element Methods for Structural Analysis
(3-0-3) Staff
Prerequisite: AME/CE 236.
An introduction to matrix methods in structural analysis and matrix methods for linear systems. The finite element stiffness method is applied to static, dynamic and stability analysis of lightweight structures. Spring.

448. Nuclear Reactor Theory
(3-0-3) Lucey
Brief review of nuclear physics, reactions of neutrons, nuclear fission, diffusion and moderation of neutrons, age diffusion and multigroup methods for bare reflected reactors, time dependent reactor behavior, heat removal from nuclear reactors. Spring.

450. Computational Fluid Dynamics
(3-0-3) F. Thomas
Prerequisite: AME 334 or AME 360.
An introduction to the fundamentals of computational aerodynamics/fluid mechanics. Numerical techniques are developed and applied to the solution of several practical fluid mechanics and aeronautics problems. Fall.

452. Energy Analysis and Diagnostics
(3-0-3) Berry, Lucey
Prerequisite: Junior status in electrical or mechanical engineering.

454. Aerospace Propulsion
(3-0-3) Staff
Prerequisite: AME 360, AME 327.
The mechanics and thermodynamics of air-breathing propulsion devices. The mechanics of various space propulsion systems are also presented, including an introduction to rocket propulsion. Fall.

456. Fundamentals of Combustion
(3-0-3) Powers
Prerequisite: AME 327, AME 439.
Thermodynamics and chemical kinetics of combustion reactions, modeling of reacting fluid mechanical systems, subsonic and supersonic combustion, detailed and one-step kinetics, ignition theory, asymptotic and numerical techniques for modeling combustion systems. Not every year.

459. Advanced Mechanics of Solids
(3-0-3) Staff
Prerequisite: AME/CE 236.
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. Fall.

460. Particle Dynamics in Atmospheric and Space Environments
(3-0-3) Dunn
Prerequisite: AME 350 or AME 334.
A senior-level undergraduate course designed to introduce the student to the subject of aerosol mechanics, with emphasis on the fundamental laws that govern particle formation, transport and deposition in atmospheric and space environments. Not every year.

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

466. Engineering Analysis of Manufacturing Processes
(3-0-3) Schmid
Prerequisite: AME/CE 236, CHEG 225.
A senior elective course dealing with the application of engineering analysis to casting, forming machining and joining processes, as well as other advanced manufacturing processes. Fall.
469. Introduction to Robotics  
(3-0-3) Goodwine  
Prerequisite: MATH 325.  
Kinematics of 2-D and 3-D robots; statics and dynamics; design considerations; actuators; sensors; control fundamentals; artificial intelligence; and vision systems. Experiments in the robotics laboratory demonstrate the fundamentals of robotics. Spring.

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

473. Dextrous Manipulators  
(3-0-3) Stanisic  
Prerequisite: AME 469 or instructor’s consent.  
A study of the kinematics of universal joint- and double-universal-joint-based manipulator wrists and arms and the use of these as subsystems within dextrous manipulators. An in-depth study of the finite and instantaneous kinematics of modern manipulator architectures. Fall.

474. Manipulation Using Vision and Estimation  
(3-0-3) Skaar  
Prerequisite: AME 469 or instructor’s consent.  
A study of tools of estimation and stochastic modeling and their use in the application of artificial vision to the guidance and control of multi-degree-of-freedom mechanisms. The Kalman filter and extended Kalman filter are developed; state and observation equations, based, respectively, on robot mechanisms and discrete visual issues of image analysis, time delay, and the modeling of random-disturbance covariances as well as kinematic holonomy. Fall.

475. Vision-Based Robotic Versatility and Precision  
(3-0-3) Skaar, Stanisic  
Prerequisites: AME 469, 473 and 474.  
The course entails application of camera-space manipulation to the control of dextrous manipulators for purposes of realizing a new system that satisfies and Industrial Partner’s “design challenge.” The course is primarily a group-design and group-fabrication/testing experience.

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

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

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

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

520. Introduction to Aeroelasticity  
521. Numerical Methods  
530. Physical Gas Dynamics  
541. Advanced Kinematic Systems  
550. Advanced Control Systems  
551. Advanced Vehicle Dynamics  
553. Introduction to Acoustics and Noise  
554. Analytical Mechanics  
558. Elasticity  
561. Mathematical Methods I  
563. Tribology

Chemical Engineering

Chair: Mark J. McCready  
Keating-Crawford Professor of Chemical Engineering: Roger A. Schmitz  
Arthur J. Schmitt Professor of Chemical Engineering: Arvind Varma  
Bayer Professor of Chemical Engineering: Hsu-chia Chang

Professors:  
Joan F. Brennecke; Jeffrey C. Kantor; James P. Kohl (emeritus); David T. Leighton Jr.; Mark J. McCready; Paul J. McGinn; Albert E. Miller; Mark A. Stadtherr; William C. Strieder; Eduardo E. Wolf

Associate Professors:  
Davide A. Hill; Edward J. Maginn

Assistant Professors:  
Agnes E. Ozaefin; Andre F. Palmer

Research Professors:  
Evgeny Demekhin; Alexander S. Moukadian

Associate Research Professor:  
Pavlo Takhistov

Assistant Research Professor:  
Alexandra E. Indeikina

Associate Professional Specialist:  
Salma R. Saddawi

Program of Studies. The Department of Chemical 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 degree of bachelor of science in chemical engineering is conferred on students who have successfully completed the required four-year program, consisting of courses in basic science and engineering, the humanities and chemical engineering.

Chemical Engineering involves the analysis and design of chemical systems; in these systems both physical and chemical transformations of matter occur. Examples of such systems are diverse, ranging from a complex petroleum refinery to the human body. While traditionally chemical engineers have been largely responsible for progress in the chemical and petroleum industries, the scope of modern chemical engineering has been increased significantly. New areas of challenge include biochemical, biomedical and environmental phenomena, as well as materials and polymer engineering, and production of microelectronic devices. In all of these areas, complex processes involving many 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 chemically reacting systems (e.g., large-scale synthesis of polymers, the artificial kidney, automotive exhaust abatement devices and production of liquid and gaseous chemicals and fuels from coal).

The curriculum in chemical engineering emphasizes chemistry, physics and mathematics, followed by the allied chemical engineering and engineering sciences, including laboratory work, and culminates in the application of principles to the analysis and design of processes.

The department presents a well-rounded program aimed at educating students to enter the various areas of chemical engineering, such as manufacturing, process and product development and technical sales, or to go on to graduate work. General professional association is prompted by the activities of a student chapter of the American Institute of Chemical Engineers.

A special course plan is available for students interested in going on to medical school following the bachelor's degree in chemical engineering. It requires a total of 133.5 semester hours and involves additional courses in biology as well as a loss of certain electives.

The Department of Chemical Engineering is located in Fitzpatrick Hall of Engineering. The laboratories are on levels A and B. The chemical engineering laboratories consist of both instructional and research laboratories. The research laboratories are primarily intended for graduate use, although room is available for a limited number of qualified undergraduates who may elect a research problem.

Further details about the chemical engineering program may be found on the World Wide Web at www.nd.edu/~chegdept. These details include the program of study requirements for graduating classes prior to the Class of 2005. The program below pertains only to the Class of 2005 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 page 260.

Sophomore Year
First Semester
MATH 251: Calculus III 3.5
CHEM 233: Organic Chemistry I 3
CHEM 233L: Organic Chemistry Lab I 1
PHYS 132: General Physics II 4
CHEG 255: Introduction to Chemical Engineering 3
Arts and Letters Course* 3
— 17.5

Second Semester
MATH 225: Calculus III 3.5
CHEM 223: Organic Chemistry I† 3
CHEM 223L: Organic Chemistry Lab I† 1
PHYS 132: General Physics II 4
CHEG 255: Introduction to Chemical Engineering 3
Arts and Letters course* 3
— 17.5

Junior Year
First Semester
MATH 325: Differential Equations 3
CHEG 355: Transport Phenomena I 3
CHEG 355L: Transport Phenomena Laboratory I 3
Arts and Letters course* 3
— 15.5

Second Semester
CHEG 256: Chemical Engineering Thermodynamics 4
CHEG 258: Computer Methods in Chemical Engineering 3
CHEG 258L: Computer Methods in Chemical Engineering Laboratory I 3
Arts and Letters course* 3
— 15.5

Senior Year
First Semester
CHEG 459: Chemical Engineering Laboratory II 3
CHEG 443: Separation Processes 3
CHEG 445: Chemical Reaction Engineering 3
Chemical Engineering Elective* 3
— 15

Second Semester
Chemical Engineering Elective* 3
CHEG 448: Chemical Process Design 3
Technical Elective* 3
Engineering/Chemistry Elective* 3
Arts and Letters course* 3
— 15

† Honor students may elect CHEM 235 and 236.
* All electives are selected from a list available in the department office.
See Arts and Letters core on page 260.

Total for the four years: 132 semester hours.
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.

(3-0-3) Miller
Prerequisite: CHEM 116 or 118.
Relation of properties and behavior of engineering materials to their structures and environments. Micro- and macrostructures of materials, phase equilibria, kinetics, structure insensitive properties, mechanical properties, surface phenomena, semiconductor phenomena, magnetic phenomena. Both semesters.

255. Introduction to Chemical Engineering
(3-0-3) McCready
Prerequisite: CHEM 116 or 118 and MATH 126.
An introduction to chemical engineering calculations, stoichiometric principles and basic energy and material balances in reacting and nonequilibrium systems.

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

258. Computer Methods in Chemical Engineering
(3-0-3) Palmer
Prerequisite: CHEG 255.
Development of numerical procedures suitable for digital computer simulation and their application to solving chemical engineering problems.

355. Transport Phenomena I
(3-0-3) Leighton
Prerequisite: CHEG 327.
Basic conservation principles of energy, mass and momentum are used to derive the integral and differential forms of the transport equations. These equations are used to solve fluid flow problems of both fundamental and practical interest.

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

358. Chemical Engineering Laboratory I
(1-4-3) Saddawi
Prerequisite: CHEG 355.
A laboratory in the determination of material properties and measurements of interest to chemical engineers. These include fluid flow, thermal conductivity of solids, gas combustion analysis by gas chromatography, natural convection and radiation, heat exchange, gas phase diffusion coefficients, liquid phase diffusion coefficients, Henry’s law, solubility and heat of solution, effective diffusivity of catalyst pellets, reverse osmosis, aerodynamic distortion, polymer molecular weight and viscoelastic solution behavior, and galvanic corrosion by potentiostatic measurements.

438. Chemical Process Control
(3-0-3) Stadtherr
Prerequisite: CHEG 356.
Development and application of mathematical models of process systems to the control and operation of such systems. Topics include time and frequency domain modeling, linear control design, effects of modeling error, interaction analysis and digital controller implementation.

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

445. Chemical Reaction Engineering
(3-0-3) Varma
Prerequisite: CHEG 356.
The basic concepts of chemical rate processes are applied to the theory of the design and operation of the various types of commercial reactors for both noncatalytic and catalytic reactions.

448. Chemical Process Design
(3-0-3) Stadtherr
An introduction to the design of chemical processing systems. Topics include an overview of the chemical process industries, process flowsheeting and process safety. Small design groups consult one of four design moderators once each week for advice and guidance on their specific process design project.

459. Chemical Engineering Laboratory II
(1-4-3) Saddawi
Prerequisite: CHEG 356.
Exercises in the applications of chemical engineering principles to the unit operations of chemical engineering. Exercises require group planning, data gathering and treatment, report writing and oral defense of the reports.

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

498. Special Studies
(V-V-3) Staff
Prerequisite: Approval of chair.
A one-credit S/U research project at the undergraduate level under the supervision of a faculty member. A written progress report describing the research project and results is required. This course must be completed before enrolling in the three-credit graded CHEG 499. Fall and spring.

499. Undergraduate Research
(V-V-3) Staff
Prerequisite: CHEG 498 and approval of chair.
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.
Civil Engineering and Geological Sciences

Chair:
Peter Burns
Henry J. Maxsim Jr. Family Chair: William G. Gray
Robert M. Moran Professor of Civil Engineering: Ahsan Kareem

Professors:
Robert L. Irvine; Stephen E. Silliman; James I. Taylor

Associate Professors:
Peter C. Burns; Jeremy B. Fein; Lloyd H. Ketchum Jr.; David J. Kirkner; Jerry J. Marley (emeritus); Patricia A. Maurice; Clive R.Neal; J. Keith Rigby Jr.; Rev. James A. Rigert, C.S.C.; Joannes J.A. Westerink

Assistant Professors:
Yahya C. Kuram; Jeffrey W. Talley

Assistant Professional Specialist:
Jinesh Jain

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 environmental engineering, master of science in bioengineering and doctor of philosophy.

Australia Program. Students majoring in civil engineering or environmental geosciences may apply to spend the fall semester of their junior year in Perth, Australia, at the University of Western Australia (UWA). During their semester abroad, students will live and learn with Australian students. The courses taken are UWA courses that are the equivalent of those required by the respective curriculum so that students can graduate on time in the normal four years. A unique feature of this program is the Field Experience course, whereby a student undertakes a small research project with a student chapter of the American Society of Civil Engineers. 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 groundwater hydrology field laboratory; a number of analytical laboratories for water, wastewater and hazardous waste treatment; and a computing room.

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

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

First Year of Studies
First-year students intending to major in civil engineering when they become sophomores will find first-year course requirements on page 260.

Sophomore Year
First Semester
MATH 225: Calculus III 3.5
PHYS 132: General Physics II 4
AM 225: Mechanics I 3
CE 242: Concepts of Civil Engineering Analysis 4
Arts and Letters course† 3
——— 17.5

Second Semester
MATH 228: Introduction to Linear Algebra and Differential Equations 3.5
AM 226: Mechanics II 3
CE 236: Mechanics of Solids 3
CE 235L: Materials/Soils Lab 2
CE 235: Civil Engineering Materials 3
Arts and Letters course† 3
——— 17.5

Junior Year
First Semester
MATH 325: Differential Equations 3
CE 336: Structural Mechanics I 3
CE 331: Stochastic Concepts in Engineering Planning and Design 3
AM 334: Fluid Mechanics 3
Arts and Letters course† 3
Free Elective/EE 222: Introduction to Electrical Science 3
——— 18

Second Semester
CE 344: Hydraulics 3
CE 442: Water Distribution and Wastewater Collection 3
CE 3X: Specialization* 3
AM 327: Thermodynamics I 3
AM 332: Fluid Mechanics Lab 2
Arts and Letters course† 3
——— 17

Senior Year
First Semester
Free Elective/EE 222: Introduction to Electrical Science 3
CE 440: Transportation Engineering 3
CE 441: Numerical Methods in Engineering 3
CE 4YY: Specialization† 3 (4)
Civil Engineering Elective† 3
——— 15 (16)

Second Semester
CE 445: Introduction to Geotechnical Engineering 3
CE 4ZZ: Specialization† 3
Technical Elective 3
Civil Engineering Elective† 3
Arts and Letters course† 3
——— 15

London Program. Students majoring in civil engineering may elect to spend the fall semester of their junior year in London. During their semester in London, students take courses offered by Notre Dame and British professors at Notre Dame’s London Centre near Trafalgar Square. The courses students take are Notre Dame courses, and credits earned are Notre Dame credits. Civil engineering students take three required engineering courses and two humanities elective courses so that they graduate with their class in the normal four years. Students participating in this program live as a group in residential facilities with supervision provided by the University. The semester enables students to combine their engineering studies with an opportunity to live and travel in Britain. Detailed information on this program can be obtained from the department office, 156 Fitzpatrick Hall, Notre Dame, IN 46556; telephone (574) 631-5380.

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 research courses.

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

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

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

Further details about the civil engineering and environmental geosciences programs may be found on the World Wide Web at www.nd.edu/~cegeos.
† The specialization course sequence CE 3XX, CE 4YY and CE 4ZZ consists of either series A or series B:
(A) Structural Sequence
CE 356: Structural Mechanics II
CE 466: Structural Steel Design
CE 486: Reinforced Concrete Design
(B) Water Resources/Environmental Sequence
CE 443: Wastewater Disposal
CE 444: Groundwater Hydrology (4)
CE 452: Introduction to Water Chemistry and Treatment
A student must complete all courses in either series A or B.
† Students may not take both CE 450 and CE 470 in fulfillment of civil engineering elective degree requirements.
* See Arts and Letters core on page 260.

Total for the four years: 134 or 135 semester hours.

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.

235. Civil Engineering Materials (3-0-3) Staff
A study of relationships between structure and properties of materials while functioning in different environments. Materials studied include metals, alloys, ceramics, polymers, composite, concrete, masonry, wood and bituminous materials.

235L. Mechanics of Solids/Materials Laboratory (0-3-2) Staff
Corequisite: CE 236.
A laboratory course to complement CE 236 and CE 235: Mechanics of Solids. Experiments on behavior of deformable solids and simple structures, materials, constitution of solids, concrete mix design and wood testing.

236. Mechanics of Solids (3-0-3) Staff
Prerequisites: AME 225, MATH 225.
An introduction to the mechanics of deformable solids. Concepts in stress, strain, stability and deformation of simple structures are introduced.

242. Concepts in Civil Engineering Analysis (3-1-4) Staff
Prerequisites: EG 112, CHEM 115, MATH 126. Corequisite: PHYS 151.
An introduction to civil engineering and methods used in civil engineering with emphasis on structural engineering, bioengineering (pollution control) and water resources.

331. Stochastic Concepts in Engineering Planning and Design (3-0-3) Kareem
Prerequisite: MATH 225. Development of probabilistic concepts and simulation models and their relevance and application to real design and decision problems encountered in civil engineering. Fall.

336. Structural Mechanics I (3-0-3) Kirkner
Prerequisite: CE 236.
Application of the principles of mechanics to the stress and deformation analysis of structural systems. Behavior and analysis of redundant structures. Fall.

344. Hydraulics (3-0-3) Gray
Prerequisite: AME 334.

356. Structural Mechanics II (3-0-3) Kirkner
Prerequisite: CE 336.
Behavior and analysis of redundant structures. General principles and methods are developed and applied to a variety of structural systems typical of civil engineering. Matrix methods of structural analysis with computer applications. Spring.

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

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

441. Numerical Methods in Engineering (3-0-3) Westerink
Prerequisite: MATH 325.

442. Water Distribution and Wastewater Collection (3-0-3) Ketchum
Prerequisite: AME 334.
Theory, analysis and design of pipe flow, sewer flow, storm and sanitary sewers, reservoirs and pumping facilities for water distribution and wastewater collection. Fall.

443. Wastewater Disposal (3-0-3) Irvine
Prerequisite: CE 344.
A study of the theory, design and operation of facilities both for industrial and municipal treatment and disposal. Design of municipal wastewater treatment systems is emphasized. Spring.

444. Groundwater Hydrology (3-0-3) Silliman
Prerequisite: Senior standing in engineering.
Lectures and laboratory cover the fundamentals of flow and transport in porous media. Methods of analysis for development of groundwater resources.

445. Introduction to Geotechnical Engineering (3-0-3) Marley
Prerequisite: CE 236.
A lecture course covering the fundamentals of geotechnical and foundation engineering. Origin, identification and classification of soils. Principles of shearing resistance, deformation, consolidation and compaction. Fall.

450. Legal, Ethical, and Business Relations in Engineering (3-0-3) Taylor
Prerequisite: Senior standing in engineering.
Legal, ethical and business relations in the practice of professional engineering. Legal aspects of contracts, intellectual property, product and professional liability. Case studies in engineering ethics. Communications, organization and interpersonal skills. Fall.

452. Introduction to Water Chemistry and Treatment (3-0-3) Staff
Prerequisites: CHEM 118, AME 334.
An introduction to water treatment design, including discussion of basic aquatic chemistry, water quality, environmental policy and current issues and problems in the industry.

453. Waste Disposal Management (3-0-3) Staff
Corequisite: CE 442.
The handling and disposal of common chemical and biological residues (both solid and semisolid) from waste collection and treatment operations.

459. Advanced Mechanics of Solids (3-0-3) Staff
Prerequisite: AME/CE 236.
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. Fall.

460. Finite Elements in Structural Mechanics (3-0-3) Kirkner
Prerequisite: CE 356 or consent of instructor.
Finite element methods for static and dynamic analysis of structural and continuum systems. Analysis of two- and three-dimensional solids as well as plates and shells. Introduction to nonlinear problems.

465. Foundations and Earth Structures (3-0-3) Staff
Prerequisite: CE 445.
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 coffee dams. Spring.
466. Structural Steel Design
(3-0-3) Staff
Prerequisite: CE 356.
The application of design theory to structural steel systems. Emphasis on structural system design using basic design fundamentals for comparison with codes of practice. Spring.

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

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

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

486. Reinforced Concrete Design
(3-0-3) Kurama
Prerequisite: CE 336.

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

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

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

525. Advanced Geostatistics
530. Environmental Chemistry
531. Introduction to Bioengineering
534. Design of Biological Waste Treatment Systems
537. Environmental Engineering Principles
539. Advanced Hydraulics
551. Fracture of Materials
554. Analytical Mechanics
556. Advanced Mechanics of Solids
563. Finite Elements in Engineering
564. Design of Timber Structures
565. Theory of Plates and Shells
569. Advanced Structural Dynamics

473/573. Environmental Engineering Design

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

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

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

An undergraduate major in environmental geosciences prepares a student for graduate study (M.S., Ph.D.) in many aspects of geology 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 B.S. degree may enter careers in a wide variety of areas, including the National Park Service, industry, environmental consulting, and government research laboratories. An environmental geosciences degree also is an ideal background for those planning to teach in secondary schools at all levels. Further details can be found at www.nd.edu/~envgeo.
The flexibility of our undergraduate program allows engineering and science students to major in environmental geosciences. Following 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 geosciences when they become sophomores will find first-year requirements on page 260.

**First Semester**
- MATH 125: Calculus I 4
- PHYS 131: Physics I 4
- Arts and Letters course$^{a}$ 3
- Physical Education/ROTC 0
- Subtotal: 11

**Second Semester**
- MATH 126: Calculus II 4
- PHYS 132: Physics II 4
- Arts and Letters course$^{a}$ 3
- Physical Education/ROTC 0
- Subtotal: 11

Total for the First Year: 22 semester hours.

**Sophomore Year**

**First Semester**
- GEOS 231: Physical Geology + Lab 4
- GEOS 242: Mineralogy 4
- Arts and Letters course$^{a}$ 3
- Field Trip 1
- Subtotal: 12

**Second Semester**
- GEOS 232: Historical Geology 4
- GEOS 247: Petrology 4
- Arts and Letters course$^{a}$ 3
- Subtotal: 11

Total for the Sophomore Year: 23 semester hours.

**Junior Year**

**First Semester**
- GEOS 357: Sediment and Stratigraphy 4
- GEOS 403: Geochemistry 3
- Arts and Letters course$^{a}$ 3
- Field Trip 1
- Subtotal: 11

**Second Semester**
- GEOS 342: Str. Geology and Rock Mech. 4
- GEOS 449: Undergraduate Research 3
- MATH 214: Introductory Statistics 3
- Arts and Letters course$^{a}$ 3
- Subtotal: 13

Total for the Junior Year: 24 semester hours.

**Senior Year**

**First Semester**
- GEOS 415: Env. Imp. Res. Utilization 3
- GEOS 423: Environmental Geochemistry 3
- CE 444: Groundwater Hydrology 4
- Arts and Letters course$^{a}$ 3
- Subtotal: 13

**Second Semester**
- GEOS 462: Environmental Mineralogy 3
- GEOS 474: Water-Rock Interaction 3
- GEOS 468: Geomicrobiology 3
- Arts and Letters course$^{a}$ 3
- Subtotal: 15

Total for the Senior Year: 28 semester hours.

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, shown in italics:

**First Year of Studies**

**First Semester**
- GEOS 131: Physical Geology + Lab 4
- CHEM 117: General Chemistry I$^{1}$ 4
- MATH 125: Calculus I 4
- Arts and Letters course$^{b}$ 3
- Physical Education/ROTC 0
- Subtotal: 17

**Second Semester**
- GEOS 103: Environmental Geosciences 3
- CHEM 116: General Chemistry II$^{2}$ 4
- MATH 126: Calculus II 4
- PHYS 131: Physics I 4
- Arts and Letters Course$^{a}$ 3
- Physical Education/ROTC 0
- Subtotal: 18

Total for the First Year: 35 semester hours.

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**

A minor in Environmental Geosciences requires the completion of 23 credit hours in geological sciences as follows:
- GEOS 131: Physical Geology + lab 4
- GEOS 232: Historical Geology 4
- GEOS 242: Mineralogy 4
- Field Trip 1
- Subtotal: 13

One of:
- GEOS 247: Petrology 4
- GEOS 342: Str. Geology and Rock Mech. 4
- GEOS 357: Sediment and Stratigraphy 4
- Subtotal: 4

Total for the Minor: 23 semester hours.

Notes:
1. CHEM 125 may be substituted for CHEM 117; CHEM 118 or 126 may be substituted for CHEM 116.
2. Technical electives are typically 300- and 400-level courses in science or engineering that have been approved by the chair of Civil Engineering and Geological Sciences. Students must ensure they have met prerequisite requirements for technical elective courses. Courses that may be used as technical electives include:
   - GEOS 458: Geophysics
   - GEOS 459: Paleontology
   - GEOS 499: Undergraduate Research
   - CHEM 224: Elem. Organic Chem. II
   - CHEM 235: Organic Chemistry + Lab
   - CHEM 236: Organic Chemistry + Lab
   - CHEM 243: Inorganic Chemistry
   - CHEM 321: Physical Chemistry
   - CHEM 322: Physical Chemistry II
   - CHEM 333: Analytical Chemistry + Lab
   - CHEM 341: Fundamentals of Biochemistry
   - CHEM 420: Principles of Biochemistry
   - BIOS 155: Biological Sciences I
   - BIOS 156: Biological Sciences II
   - BIOS 201: General Biology I
   - BIOS 202: General Biology II
   - BIOS 401: Principles of Microbiology
   - AME 225: Mechanics I
   - AME 226: Mechanics II
   - AME 334: Fluid Mechanics
   - CE 344: Hydraulics
   - CE 452: Int. Water Chem. and Treatment
   - CE 443: Wastewater Disposal
   - MATH 325: Differential Equations
3. University requirements include:
   - FYC 110 3
     + Theology 6 hours
     + Philosophy 6 hours
     + History 3 hours
     + Social Science 3 hours
     + Fine Arts or Literature 3 hours
     + One of these courses must be a University Seminar 180.

4. If GEOS/SC 231 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.

103. Environmental Geosciences (3-0-3) Fein
Prerequisites: Open to all first-year students. This course introduces the student to Earth processes and focuses on how these processes affect people, and how people affect these processes. The course explores the interactions between Earth’s biosphere, geosphere, atmosphere, and hydrosphere, with the objective of demonstrating how our physical environment is controlled by geological, biological, and human forces.

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

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

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

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

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

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

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

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

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

415. Environmental Impact of Resource Utilization (3-0-3) Neal
Prerequisites: GEOS 242, GEOS 403, or consent of instructor. The environmental effects of utilizing natural resources are examined from their extraction, refining, to use. Pivotal in this course is environmental impact assessment and rehabilitation/remediation technologies. A number of case studies will be examined to highlight the environmental impact of using the Earth’s natural resources and how such impacts can be mitigated.
423. Environmental Geochemistry
(3-0-3) Maurice
Prerequisites: GEOS 403 or consent of instructor.
The fundamental controls on bacterial adhesion.
and dissolution, photoredox phenomena, and con-
trols on bacterial adhesion.

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

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

459. Paleontology
(2-2-3) Rigby
Prerequisites: GEOS 232 or consent of instructor.
The fossil record – morphology, taxonomy, evolu-
tion, statistical population systematics and paleo-
ecology. A one-day field trip is required.

462. Environmental Mineralogy
(3-0-3) Burns
Prerequisites: GEOS 424 or consent of instructor.
This course explores the chemistry and structures of
minerals with emphasis on environmental and
technological issues. Topics of environmental sig-
nificance include disposal of spent nuclear fuel,
contamination of soils with heavy metals, and the
remediation of mine tailings. Emphasis will be on
the mineralogy of uranium, lead, mercury, iodine,
selenium, and tellurium. Technological aspects of
minerals, such as the use of zeolites and clay miner-
als as molecular sieves and as waste containment
vessels, will be addressed.

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

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

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

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

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

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

403/503: Geochemistry
519: Surface and Subsurface Geophysics
528: ICP Analytical Techniques
545: Biogeochemical Cycles
547: Geodynamics
568: Environmental Isotope Geochemistry

Computer Science
and Engineering

Schubmehl/Preiss Chair of Computer Science
and Engineering:
Kevin W. Bowyer

Ted H. McCourtney Professor of Computer Science
and Engineering:
Peter M. Kogge

Professors:
Steven C. Buss (emeritus); Danny Z. Chen;
Eugene W. Heny (emeritus); John J. Uhran Jr.

Associate Professors:
Jay B. Brockman; Patrick Flynn; X. Sharon Hu

Assistant Professors:
Vincent W. Freeh; Jesu A. Izaguirre; Matthias
Scheutz; Lambert Schaelieck

Professional Specialist:
Gregory R. Mader

Assistant Professional Specialist:
Ramzi K. Buahlan

J. Curt Freeland

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

London Program. Students majoring in Com-
puter Science and Computer Engineering may
apply to spend the fall semester of their junior year
in London. During their semester in London, stu-
dents take courses offered by Notre Dame and
British professors at Notre Dame’s London Centre
near Trafalgar Square. The courses taken by the
students are Notre Dame courses, and credits
earned are Notre Dame credits. The students take
two required engineering courses, one mathematics
course, and two humanities elective courses so that
they graduate with their class in the normal four
years. Students participating in this program live as
a group in residential facilities, with supervision
provided by the University. The semester enables
students to combine their engineering studies with
an opportunity to live and travel in Britain. De-
tailed information on this program can be obtained
from the department office in 384 Fitzpatrick Hall,
Notre Dame, IN 46556; telephone (574) 631-
8321; fax (574) 631-9260.
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 which are used by undergraduates as well. Moreover, the department uses UNIX workstations, which support modern computer-aided design tools for the design of computer systems and integrated circuits (VLSI) in many courses. Also available is a laboratory for the fabrication of integrated circuits designed by students in the "bits-to-chips" program.

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

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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.

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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.

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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 page 236.

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Computer Engineering Program:

Sophomore Year

<table>
<thead>
<tr>
<th>First Semester</th>
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<tbody>
<tr>
<td>CSE 211: Fundamentals of Computing I</td>
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<tr>
<td>CSE 210: Discrete Mathematics</td>
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<tr>
<td>MATH 225: Calculus III</td>
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<tr>
<td>PHYS 132: General Physics II</td>
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<tr>
<td>Arts and Letters course’</td>
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<td>Total Semester Credits:</td>
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<table>
<thead>
<tr>
<th>Second Semester</th>
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<tbody>
<tr>
<td>CSE 212: Fundamentals of Computing II</td>
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<tr>
<td>CSE 221: Logic Design</td>
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<tr>
<td>MATH 228: Introduction to Linear Algebra and Differential Equations</td>
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<tr>
<td>Technical Elective</td>
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<td>Arts and Letters course’</td>
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<td>Total Semester Credits:</td>
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Junior Year

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<tr>
<th>First Semester</th>
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<tbody>
<tr>
<td>CSE 331: Data Structures</td>
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<tr>
<td>CSE 321: Computer Architecture I</td>
</tr>
<tr>
<td>EE 224: Introduction to Electrical Engineering</td>
</tr>
<tr>
<td>Free Elective</td>
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<tr>
<td>Arts and Letters course’</td>
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<td>Total Semester Credits:</td>
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<table>
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<tr>
<th>Second Semester</th>
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<tbody>
<tr>
<td>CSE 322: Computer Architecture II</td>
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<tr>
<td>CSE 341: Operating System Principles</td>
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<tr>
<td>EE 234: Electric Circuits</td>
</tr>
<tr>
<td>MATH 323: Probability</td>
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<tr>
<td>Arts and Letters course’</td>
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<tr>
<td>Total Semester Credits:</td>
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Senior Year

<table>
<thead>
<tr>
<th>First Semester</th>
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<tbody>
<tr>
<td>EE 344: Signals and Systems I</td>
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<tr>
<td>CSE Electives*</td>
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<tr>
<td>Free Elective</td>
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<tr>
<td>Total Semester Credits:</td>
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<tr>
<th>Second Semester</th>
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<tbody>
<tr>
<td>CSE 475: Computing and Society</td>
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<tr>
<td>EE 242: Electronics I</td>
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<tr>
<td>CSE Elective*</td>
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<tr>
<td>Arts and Letters course’</td>
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<tr>
<td>Total Semester Credits:</td>
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</tbody>
</table>

Total Semester Credits: 131
Computer Science Program:

Sophomore Year

First Semester
CSE 211: Fundamentals of Computing I 4
CSE 210: Discrete Mathematics 3
MATH 223: Calculus III 3.5
PHYS 132: General Physics II 4
Arts and Letters course* 3
Total Semester Credits: 17.5

Second Semester
CSE 212: Fundamentals of Computing II 4
CSE 221: Logic Design 4
MATH 228: Introduction to Linear Algebra and Differential Equations 3.5
Technical Elective 3
Arts and Letters course* 3
Total Semester Credits: 17.5

Junior Year

First Semester
CSE 331: Data Structures 3
CSE 321: Computer Architecture I 4
CSE Elective* 3
Technical Elective 3
Arts and Letters course* 3
Total Semester Credits: 16

Second Semester
CSE 411: Automata 3
CSE 341: Operating System Principles 3
CSE Elective* 3
MATH 323: Probability 3
Arts and Letters course* 3
Total Semester Credits: 15

Senior Year

First Semester
CSE 413: Algorithms 3
CSE Elective* 6
Technical Elective 3
Free Elective 3
Total Semester Credits: 15

Second Semester
CSE 475: Computing and Society 3
CSE Electives* 6
Arts and Letters course* 3
Total Semester Credits: 12

Total Semester Credits: 128

* See Arts and Letters core on page 260.
* These courses must be selected from a list approved by the department. For computer engineering, at least one must be a designated design course.

Computer Science and Engineering Course Descriptions

210. Discrete Mathematics
(3-0-3) Staff
Prerequisite: CSE 232.
Introduction to mathematical techniques fundamental to computer engineering and computer science. Topics: mathematical logic, induction, set theory, relations, functions, recursion, recurrence relations, introduction to asymptotic analysis, algebraic structures, graphs, machine computation.

211. Fundamentals of Computing I
(3-1-4) Scheutz
Prerequisites: EG 111, EG 112.
This is the first part of a two-course introduction-to-computing sequence, intended primarily for Computer Science and Computer Engineering majors. It introduces fundamental concepts and principles of computer science, from formulating a problem and analyzing it conceptually, to designing, implementing, and testing a program on a computer. Using data and procedural abstractions as basic design principles for programs, students learn to define basic data structures, such as lists and trees, and to apply various algorithms for operating on them. The course also introduces object-oriented and parallel programming methods. The primary programming language used in this course is SCHEME.

212. Fundamentals of Computing II
(3-0-3) Staff
Prerequisite: CSE 211.
This is the second part of a two-course introduction-to-computing sequence, intended primarily for Computer Science and Computer Engineering majors. This course introduces concepts and techniques for developing large software systems. The object-oriented model of design and programming is presented using a modern programming language such as Java or C++. Topics covered include modularity, specification, data abstraction, classes and objects, genericity, inheritance, subtyping, design patterns, testing, concurrency, object persistence, and databases.

221. Logic Design and Sequential Circuits
(3-3-4) Staff
Prerequisite: CSE 232.
Boolean algebra and switching circuits, Karnaugh maps, design of combinational and of sequential logic networks, sequential machines.

223. Functional Programming
(3-0-3) Staff
Prerequisite: 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.

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

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

341. Operating System Principles
(3-0-3) Maday
Prerequisite: CSE 321.
Corequisite: CSE 322.
Introduction to all aspects of modern operating systems. Topics include process structure and synchronization, interprocess communication, memory management, file systems, security, I/O and distributed files systems.
346. Database Concepts  
(3-0-3) Bualuan  
Prerequisite: CSE 331.  
Effective techniques in managing, retrieving and updating information from a database system. Focusing primarily on relational databases, the course presents the entity-relationship model, query processing and normalization. Topics such as relational calculus and algebra, integrity constraints, distributed databases and data security will also be discussed. A final project will consist of the design and implementation of a database system.  

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

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

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

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

439. Computer Simulation  
(3-0-3) Staff  
A survey of computer techniques to simulate operating characteristics of stochastic dynamic systems. Topics include problem formulation, data collection, simulation programming in both a general-purpose language and a specialized language, random number generation, random variate generation, design of simulation experiments, interpretation of simulated output, and model verification and validation.  

443. Compilers  
(3-0-3) Freeth  
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; runtime environments; and code generation.  

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

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

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

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

466. Computer Graphics  
(3-0-3) Staff  

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

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

Chair:
Yih-Fang Huang
H.C. and E.A. Broudy Professor of Electrical Engineering

Panagiotis J. Antsaklis
Leonard Better Chair of Electrical Engineering in Communications:
Daniel J. Costello Jr.
Frank M. Freimann Professor of Electrical Engineering:
Ruey-wen Liu
Frank M. Freimann Professor of Electrical Engineering (emeritus):
James L. Merz
Frank M. Freimann Professor of Engineering:
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; Oliver M. Collins; Daniel J. Costello Jr.; Thomas E. Fuja; Eugene W. Henry (emeritus); Yih-Fang Huang; Joseph C. Hogan (emeritus); Craig S. Lent; Alan C. Sabaugh; Robert L. Stevenson; John J. Uhran Jr.

Associate Professors:
Garabert J. Gabriel (emeritus); Douglas C. Hall; Thomas H. Kosel; Michael D. Lemmon; Ken D. Sauer; R. Michael Schafer (adjunct); Gregory L. Snider

Assistant Professors:
Patrick J. Fay; Martin Haenggi; John B. Kenney (adjunct)

Research Associate Professor:
Alexander Miniairov; Alexei Orlov

Assistant Professional Specialist:
John Ott

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.

London Program. Students majoring in Electrical Engineering may apply to spend the fall semester of their junior year in London. During their semester in London, students take courses offered by Notre Dame and British professors at Notre Dame’s London Centre near Trafalgar Square. The courses taken by the students are Notre Dame courses, and credits earned are Notre Dame credits. The students take two required engineering courses, one mathematics course and two humanities elective courses so that they graduate with their class in the normal four years. Students participating in this program live as a group in residential facilities, with supervision provided by the University. The semester enables students to combine their engineering studies with an opportunity to live and travel in Britain. Detailed information on this program can be obtained from the university office in 275 Fitzpatrick Hall, Notre Dame, IN 46556; telephone (574) 631-5480; fax (574) 631-4393.

Program in Electrical Engineering. The four-year curriculum, listed below, includes required and elective courses in the pure and applied sciences, the humanities and electrical engineering. Emphasis is on the mastery of fundamental principles, with added depth and provision for specialization in the following major professional areas of communications, control systems, electronic circuits, design and analysis, microelectronics and integrated circuits, fabrication, photonics, and signal processing. Students are individually assisted and advised in their choices of elective courses.

Departmental facilities include laboratories for electronics, circuits, electrophysics, control systems, communications, integrated circuit fabrication and photonics. State-of-the-art computers are available for use in all classes.

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

First Year of Studies
First-year students intending to major in electrical engineering when they become sophomores will find first-year course requirements on page 260.

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

Second Semester
MATH 228: Introduction to Linear Algebra and Differential Equations 3.5
PHYS 231: General Physics III 3.5
EE 242: Electronics I 4
EE 234: Electric Circuits 3
CSE 221: Logic Design 4
Total 15

Junior Year
First Semester
MATH 325: Differential Equations 3
EE 344: Signals and Systems I 3
EE 347: Semiconductors I 3
EE 348: Electromagnetic Fields and Waves I 3
Arts and Letters course† 3
Total 15

Second Semester
MATH 325: Probability 3
EE 330: Engineering Design 1
Electrical Engineering Electives* 6
Technical Electives† 3
Arts and Letters course† 3
Total 16

Senior Year
First Semester
EE 430: Senior Design I 2
Electrical Engineering Electives* 6
Engineering Science Elective† 3
Arts and Letters course† 3
Total 15

Second Semester
EE 440: Senior Design II 2
Electrical Engineering Electives* 6
Technical Electives† 3
Arts and Letters course† 3
Total 14

Total for four years: 128.5 semester hours.

* At least one electrical engineering elective must be chosen from EE 342, 446, 455, 458, and 468.
† See Arts and Letters course on page 260.
‡ The engineering science elective must be chosen from AME 327, CHEG 327, CHEG 225 or AME 225.
§ The technical elective must be chosen from the approved technical elective course list.

Electrical 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.

222. Introduction to Electrical Science (3-0-3) Kosel
Corequisites: MATH 225 and PHYS 132.
An introduction to the analysis of electrical circuits, devices and systems, which provides the basis for continued study in the electrical sciences. Fall.
224. Introduction to Electrical Engineering  
(3-3-4) Lemmon  
*Corequisites:* MATH 225 and PHYS 132.  
A project-oriented introduction to electrical engineering principles in which long-term projects are used to introduce such topics as node and loop analysis, network theorems, first-order circuits, operational amplifiers, communication, systems theory, microprocessor interfacing techniques, and computer programming. Fall.

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

242. Electronics I  
(3-3-4) Stevenson  
*Prerequisite:* EE 222 or 224.  

330. Principles of Engineering Design  
(1-0-1) Berry  
This course introduces the student to the principles of design. Through a series of lectures and projects, students will learn effective methods for taking potential products from concept to production. Spring.

342. Electronics II  
(3-3-4) Seabaugh  
*Prerequisite:* EE 222 or 224.  
Fundamentals of transistor integrated circuit design, including frequency response, feedback, stability, and frequency compensation with application to operation amplifiers, phase-locked loops, and AM/FM transmission and reception. Includes laboratory. Spring.

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

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

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

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

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

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

430. Senior Design I  
(0-6-2) Huang  
The first part of a yearlong senior design project. In this part, students will choose a project, develop the paper design, plan the implementation and purchase necessary materials. Fall.

440. Senior Design II  
(0-6-2) Huang  
The second part of a yearlong senior design project. In this part, students implement, test and document their senior project. Spring.

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

452. Energy Analysis and Diagnostics  
(3-0-3) Berry  

453. Communication Systems  
(3-0-3) Fuja  
*Prerequisites:* MATH 323, EE 354.  
An introduction to the generation, transmission and detection of information-bearing signals. Analog and digital modulation techniques including AM, FM, PSK, QAM, and PCM. Time and frequency division multiplexing. Fall.
455. Control Systems
(3-0-3) Antsaklis
Prerequisites: EE 354, MATH 325.
Design of linear feedback control systems by state-variable methods and by classical root locus, Nyquist, Bode and Routh-Hurwitz methods. Fall.

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

458. Microwave Circuit Design and Measurements Laboratory
(2-3-3) Fay
Prerequisite: EE 358 or consent of instructor.
This course is an introduction to microwave circuit design and analysis techniques, with particular emphasis on applications for modern microwave communication and sensing systems. An integrated laboratory experience provides exposure to fundamental measurement techniques for device and circuit characterization at microwave frequencies. Students will develop an enhanced understanding of circuit design and analysis principles as applied to modern microwave circuits, as well as become familiar with design techniques for both hand analysis and computer-aided design. An appreciation for basic measurement techniques for characterization of microwave devices, circuits and systems through laboratory experiments will also be developed. Fall.

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

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

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

466. Topics in Electronic Transport Theory
(3-0-3) Potok
Prerequisite: EE 357.

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

471. Digital Signal Processing
(3-0-3) Haenggi
Prerequisite: EE 354 and MATH 323.

476. Electronic Properties of Materials
(3-0-3) Kozel
Prerequisite: EE 347 or equivalent.

477. Photovoltaics — Fundamentals of Solar Cells
(3-0-3) Berry
Prerequisite: EE 347 or equivalent.
A study of the materials and device properties of photovoltaic devices — solar cells. The criteria for both space and terrestrial applications are considered. Comparisons are made between thin film, polycrystalline and crystalline cells.

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

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

499. Undergraduate Research
(V-V-V) Staff
A research project at the undergraduate level under the supervision of a faculty member. The following graduate courses, described in the Graduate School Bulletin of Information, are also open to advanced undergraduates with permission of the department chair.

550. Linear Systems

551. Mathematical Programming

553. Advanced Digital Communications

554. Computer Communication Networks

555. Multivariable Control Systems

556. Fundamentals of Semiconductor Physics

558. Microwave Theory

561. Multi-Dimensional Signal Processing

563. Random Variables and Stochastic Processes

566. Solid State Devices

568. Electromagnetic Theory I

571. Statistical Signal Processing

576. Submicron Fabrication Techniques

580. Nonlinear Control Systems

581. Digital Image Processing
Interdepartmental Engineering

Course Descriptions

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

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

112. Introduction to Engineering Systems II
(3-0-3) Staff
Prerequisite: First-year standing.
The second of a two-course sequence intended to continue the introduction of First-Year intents to the engineering disciplines. 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.

200. EPICS: Engineering Projects in Community Service
(V-V-V) Staff
Prerequisite: Sophomore standing.
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.

300. EPICS: Engineering Projects in Community Service
(V-V-V) Staff
Prerequisite: Junior standing.
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.

400. EPICS: Engineering Projects in Community Service
(V-V-V) Staff
Prerequisite: Senior standing.
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.

Dual Degree Programs

DUAL DEGREE PROGRAM WITH THE COLLEGE OF ARTS AND LETTERS

Coordinators:
John J. Uhran Jr.
Associate dean
College of Engineering
Ava Preacher
Assistant dean
College of Arts and Letters

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

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

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

University Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philosophy</td>
<td>6</td>
</tr>
<tr>
<td>Theology</td>
<td>6</td>
</tr>
<tr>
<td>Composition</td>
<td>3</td>
</tr>
<tr>
<td>University Seminar</td>
<td>(3)</td>
</tr>
<tr>
<td>History</td>
<td>3</td>
</tr>
<tr>
<td>Social Science</td>
<td>3</td>
</tr>
<tr>
<td>Literature or Fine Arts</td>
<td>5</td>
</tr>
<tr>
<td>Mathematics (MATH 125, 126)</td>
<td>8</td>
</tr>
<tr>
<td>Natural Science (CHEM 117, 116)</td>
<td>7</td>
</tr>
</tbody>
</table>
## Schematic Program of Studies

### First Semester
- AL 211, 212: Introduction to Engineering Systems I 3
- CHEM 117: General Chemistry I 4
- EG 111: Introduction to Engineering Systems I 3
- Physical Education — 2

**Total:** 17/180

### Second Semester
- FYC 110: Composition 3
- MATH 125: Calculus I 3
- CHEM 116: General Chemistry II 4
- EG 112: Introduction to Engineering Systems II 3

**Total:** 17

### Third Semester
- Theology/Philosophy 3
- PHYS 131: General Physics I 4
- MATH 126: Calculus II 4
- AL 211: Ideals, Values and Images 3

**Total:** 19.5

### Fourth Semester
- Theology/Philosophy 3
- AL 212: Ideals, Values and Images 3
- Modern Language 3
- MATH 228: Linear Algebra and Differential Equations 3.5

**Total:** 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

**Total:** 18

### Sixth Semester
- Literature* 3
- History/Social Science 3
- Engineering Program 3
- Engineering Program 3
- Arts and Letters Major† 3
- Engineering Program 3

**Total:** 18

### Seventh Semester
- Fine Arts* 3
- Engineering Program 3
- Arts and Letters Major 3
- Engineering Program 3

**Total:** 18

### Eighth Semester
- Engineering Program 3
- Engineering Program 3
- Arts and Letters Major 3
- Arts and Letters Major 3

**Total:** 18

### Ninth Semester
- Engineering Program 3
- Engineering Program 3
- Arts and Letters Major 3
- Arts and Letters Major 3

**Total:** 18

### Tenth Semester
- Engineering Program 3
- Engineering Program 3
- Engineering Program 3

**Total:** 15

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**Notes:**
- * 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 170 to 180 credit hours.
- † Courses necessary to fulfill the requirements for a major in the student’s major arts and letters department.

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## Arts and Letters Requirements

- AL 211, 212 6
- Literature or Fine Arts* 3
- History or Social Science 3
- Language** 6/9
- Major (minimum) 24

**Total:** 42/45

## Engineering Requirements

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

**Total:** 21

## Engineering Program

Engineering degree program

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>(required courses and program or technical electives)</td>
<td>68/75</td>
</tr>
</tbody>
</table>

**Total:** 170/180

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### 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 the chosen field 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 an engineering degree program. Students interested in making application for the M.B.A./engineering program should apply to the M.B.A. program during their junior year. To facilitate the application process, students should take the Graduate Management Admission Test (GMAT) either in June following their sophomore year or in October during the fall semester of their junior year.

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

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### Dual Degree Program with the Mendoza College of Business

**Coordinators:**
- Hayden Estrada
  - Director of admissions
- John J. Uhran Jr.
  - Associate dean
- College of Engineering
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, 100.5-104.5 credit hours.

**Summer Session following junior year:**
Arts and Letters course
Arts and Letters course
MBA 503: Excel Workshop
MBA 504: Career Development

**Senior Year**

<table>
<thead>
<tr>
<th>First Semester</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>MGT 500: Statistics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>FIN 510 Microeconomics*</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ACCT 500: Accounting</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>MARK 500: Marketing Management</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>MBA 500: Management Communication I</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Engineering courses</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.5</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN 500: Financial Management</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>FIN 515: Global Macroeconomic Environment</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>MGT 515: Operations Management</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>MBA 501: Management Communication II</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Engineering courses</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.5</strong></td>
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**Fifth Year**

<table>
<thead>
<tr>
<th>First Semester</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>FIN 510: Microeconomic Analysis</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>MGT 510: Organizational Behavior</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Business Ethics Elective</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>International Business Elective</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Engineering courses</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MGT 519: Corporate Strategy</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>M.B.A. Electives</td>
<td>12</td>
<td></td>
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<tr>
<td>Engineering course</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18</strong></td>
<td></td>
</tr>
</tbody>
</table>

* See Arts and Letters core on page 260.
* If Statistics is waived.
** Occurs during August Orientation.

Total for both degrees: 128.5-134.5 undergraduate, 48 M.B.A.

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

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Senior Associate Dean of the College of Engineering

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Associate Dean of the College of Engineering

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