



Table of Contents

Degrees Offered and Associated Departments	143
Overview of Undergraduate Programs	143
Overview of Graduate Programs	147
Biomedical Engineering	148
Chemical and Biological Engineering	155
Civil and Environmental Engineering	163
Decision Sciences and Engineering Systems	174
Electrical, Computer, and Systems Engineering	188
Materials Science and Engineering	206
Mechanical, Aerospace, and Nuclear Engineering	212
Engineering at Hartford	228
Interdisciplinary Degree Programs	234
Engineering Science	234
Product Design and Innovation	235
Interdisciplinary Research Centers	237
Center for Earthquake Engineering Simulation	237
Flexible Manufacturing Center	238
Center for Image Processing Research	238
Center for Infrastructure and Transportation Studies	239
Center for Multiphase Research	240
Center for Subsurface Sensing and Imaging Systems	241

School of Engineering

Dean: Alan W. Cramb

Associate Deans: Joe H. Chow, Lester A. Gerhardt, Richard N. Smith

Director of Core Engineering: Mark W. Steiner

School of Engineering Home Page: <http://www.eng.rpi.edu>

Rensselaer's School of Engineering is committed to technological excellence in integrating research and education and in educating for career success.

Outstanding leadership in innovative and progressive education is a Rensselaer hallmark. Rensselaer is renowned for producing visionary and versatile technological leaders with a superior reputation for their global impact. Solidly endowed with the fundamentals of math, science, and engineering as well as invaluable research, communication, and entrepreneurial expertise, Rensselaer engineering graduates demonstrate an exceptional propensity for practical application of their knowledge. In addition, the inclusion of a strong humanities and social sciences component within this broad education and a full spectrum of activities, both in and out of the classroom, enhance human relations skills and generate a commitment to ethical behavior and social responsibility.

Highly cognizant of the constant evolution in the field of engineering, Rensselaer is dedicated to continually enhancing and revitalizing its curricula and facilities. Evidence of this dedication is its initiatives in such emerging fields as information technology, biotechnology, and nanotechnology. Among these are the new biotechnology and interdisciplinary research building, the ongoing attraction of leaders in these fields to our already excellent engineering faculty, and the development of expanded opportunities for research within these and other developing fields at both the graduate and undergraduate levels.

Key to promoting such new initiatives, as well as enhancing traditional disciplines, is Rensselaer's world-class faculty, all of whom hold the highest attainable degree in their fields. In addition to being actively engaged in research and teaching, most also keep their finger on the pulse of the world through consulting or entrepreneurial endeavors.

Especially appealing to Rensselaer's exceptional faculty and students alike are its superlative laboratories and facilities that enable them to conduct outstanding research and innovation in education pedagogy. These include studio classrooms that, in addition to being equipped with highly advanced interactive learning tools, provide the small comfortable environment that enhances the School of Engineering's personalized approach to teaching, maximizing student interaction among classmates and professors, and encouraging hands-on, collaborative projects.

Commitment to mobile computing and interactive delivery are also features that distinguish Rensselaer engineering programs from those at other universities. As noted in the Educational Programs and Resources section of this catalog, the Institute mandated that all undergraduate students have laptop computers as of the fall of 2002. This mandate was issued in recognition that the entire world is moving in the direction of near constant computer access. In addition, the program supports the interactive delivery initiative, in which lectures are combined with recitation, modeling, simulation, and laboratory exercises. Unlike the traditional professor-centered straight lecture format, interactive delivery centers on the students and allows them to interact with each other as well as the instructor. Through these new programs, students experience greater freedom, are no longer tied to a desk for their computing needs, and are prepared for what they will find in the real world.

Teamwork is yet another aspect of real-world engineering practice that Rensselaer cultivates through both its coursework and facilities. A prime example is the Institute's 11,000 square-foot O.T. Swanson Multidisciplinary Design Laboratory (MDL). This distinctive, first-class facility consists of a state-of-the-art design space, rapid prototyping and fabrication space, and a system integration space for both mechanical and electrical as well as electromechanical products. Here, students work in cross-disciplinary teams on a variety of industry- and service organization-sponsored and entrepreneurial projects, all with practical and real-life applications.

Augmenting the course experience for both undergraduate and graduate students is access to numerous research centers and computing resources. These include one of the largest Class 100 clean-room facilities on an academic campus, a 100-ton-g centrifuge, a linear accelerator (LINAC), the Advanced Manufacturing Laboratories, and the student-faculty shop. Engineering students use extensive interactive workstation facilities for studies in computer-aided design, analysis, and/or manufacturing. Taught and researched in the clean-rooms are integrated circuit and interconnect technology. The centrifuge, part of an NSF-funded CEES center, is used for geotechnical research and is a state-of-the-art facility. The manufacturing laboratories provide students an opportunity to design and manufacture their own product to realistic specifications.

Other specialized and more discipline-oriented facilities include laboratories in areas such as fluidization, heat transfer, biological engineering, biomedical engineering, structures, earthquake engineering, image processing, plasma dynamics, mechatronics, microelectronics, microwaves, photonics, electrical machines, power systems and electronics, electron microscopy and materials characterization, subsonic and supersonic flow, tribology, viscoelasticity, two-phase flow, mass spectrometry, and ion physics.

Sponsoring both undergraduate and graduate research are a variety of government (federal and state) agencies as well as private industry. As a result of focusing research on topics of significant commercial interest, Rensselaer, in relation to other major university engineering programs, has one of the largest fractions of support from private industry.

Rensselaer offers research opportunities in major interdisciplinary research centers, which primarily involve School of Engineering faculty and students. Among these centers are the Academy for Electronic Media, Center for Automation Technologies and Systems (CATS), Center for Biotechnology and Interdisciplinary Studies, the Center for Integrated Electronics (CIE), NYS Center for Future Energy Systems, The Center for Nanotechnology Research, and the Scientific Computation Research Center (SCOREC). These centers are interdisciplinary, so that center projects include students from each of several curricula. For example, in the CIE, students from many departments (e.g., Physics; Materials Science and Engineering; Mechanical, Aerospace; and Nuclear Engineering; Electrical, Computer, and Systems Engineering; Chemical and Biological Engineering; and Civil and Environmental Engineering) are members of teams that conduct government- and industry-supported basic and applied research.

Projects in CIE currently under way include multilevel interconnects, chemical-mechanical polishing, polymers for interlevel dielectrics, compound semiconductors, and wireless manufacturing programs that employ flexible technologies and organizations, as well as improved communications to help solve manufacturing problems. Also world-renowned is SCOREC's simulation-based engineering approach in which state-of-the-art computers and numerical models are applied to problems of great societal need.

In addition to the major Institute centers, the School of Engineering conducts research in its own multidisciplinary centers. These include the Center for Infrastructure and Transportation Studies, Center for Fuel Cell and Hydrogen Research, the Center for Image Processing Research, the Center for Multiphase Research, and the Center for Earthquake Engineering Simulation. At the department level, the School offers seven additional centers: the Bioseparations Research Center, the Center for Services Research and

Education, the Statistical Consulting Center, and the Center for Glass Science and Technology.

Substantial Rensselaer research is also conducted outside these major centers, some involving multiuniversity collaboration. These research centers complement the following seven academic departments: Biomedical Engineering; Chemical and Biological Engineering; Civil and Environmental Engineering; Decision Sciences and Engineering Systems; Electrical, Computer, and Systems Engineering; Materials Science and Engineering; and Mechanical, Aerospace, and Nuclear Engineering.

All departments offer both undergraduate and graduate curricula and degree programs in their fields. In the list below, programs associated with post-baccalaureate degrees only are indicated by (G).

Degrees Offered and Associated Departments

Aeronautical Engineering	Mechanical, Aerospace, and Nuclear Engineering
Biomedical Engineering	Biomedical Engineering
Chemical Engineering	Chemical and Biological Engineering
Civil Engineering	Civil and Environmental Engineering
Computer Systems Engineering	Electrical, Computer, and Systems Engineering
Decision Sciences and Engineering Systems (G)	Decision Sciences and Engineering Systems
Electric Power Engineering	Electrical, Computer, and Systems Engineering
Electrical Engineering	Electrical, Computer, and Systems Engineering
Engineering Physics	Mechanical, Aerospace, and Nuclear Engineering
Engineering Science (G)	School of Engineering
Environmental Engineering	Civil and Environmental Engineering
Industrial and Management Engineering	Decision Sciences and Engineering Systems
Manufacturing Systems Engineering (G)	Decision Sciences and Engineering Systems
Materials Engineering	Materials Science and Engineering
Mechanical Engineering	Mechanical, Aerospace, and Nuclear Engineering
Mechanics (G)	Mechanical, Aerospace, and Nuclear Engineering
Nuclear Engineering	Mechanical, Aerospace, and Nuclear Engineering
Nuclear Engineering and Science (G)	Mechanical, Aerospace, and Nuclear Engineering
Operations Research and Statistics (G)	Decision Sciences and Engineering Systems
Transportation Engineering (G)	Civil and Environmental Engineering

Overview of Undergraduate Programs

Baccalaureate Program

In general, the Bachelor of Science program is intended for students seeking careers in engineering-related areas or as a basis for advanced study in fields other than engineering. To obtain a B.S. in an engineering field, students must fulfill the general requirements listed in the Academic Information and Regulations section of this catalog and satisfactorily complete the prescribed engineering curriculum. Certain courses, such as one-credit-hour nonengineering courses graded on a satisfactory/unsatisfactory basis or more than six credit hours of ROTC courses, cannot be applied toward the degree requirements. Also noteworthy is that courses in accounting, industrial management, finance, entrepreneurship, and personnel administration that are offered by the School of Management, as well as ROTC courses, will not satisfy the humanities and social sciences requirement, but may be taken as free electives.

Although many students enter at the freshman level and achieve all their education objectives at Rensselaer, a significant number find it accommodating and advantageous to enter at intermediate levels. Entrance into the engineering program is particularly attractive to graduates of two-year colleges. All such students enter with advanced standing and credit according to their credentials.

Professional Program

For most students, specialization and determination of the degree program that matches their individual career goals takes place during the third year. At this point, a student may pursue either a fourth year for their Bachelor of Science (B.S.) degree in an engineering specialty or, if accepted by the Office of Graduate Education for the Professional Program, undertake a coherent program integrating advanced undergraduate and graduate study leading to the Master of Engineering (M.Eng.) degree in a specific field, and receiving a Bachelor of Science along the way. This professional program offers post-baccalaureate studies specifically intended as preparation for professional engineering practice. Graduates of other colleges and universities may be admitted with advanced standing (the Professional Program excepted) if they have appropriate accredited baccalaureate engineering degrees or the equivalent. Admission to a professional degree program is based on demonstration of adequate preparation and competence. The faculty in each curriculum judges qualifications for admission. Application should be made directly to the Office of Graduate Education.

Engineering Core Curriculum

The core engineering program forms the foundation for all engineering curricula. In addition to providing a solid base for later specialization, it allows students who are undeclared as to their choice of engineering field or discipline an opportunity to clarify their interests. Such students can, by using the electives in the first two years, sample various disciplinary offerings to aid in choosing which engineering field to pursue.

The core engineering curriculum in the general format is presented on the following pages. Specific curricula for each field of specialization are presented under the corresponding disciplinary headings for students who are certain of their disciplinary choices and wish to begin specializing earlier than the third year. Two kinds of programs are listed under each discipline: (1) a four-year baccalaureate program leading to the Bachelor of Science degree; (2) a professional program, taken in the fourth and fifth years, leading to the B.S. and M.Eng. degrees.

While undergraduates normally are not allowed to take graduate-level courses (levels 6000–9000) except by special permission of the instructor, a student admitted to the Professional School may be required to take certain courses in the 6000–9000 range and may elect other such courses with the approval of his or her adviser.

All School of Engineering students entering Rensselaer directly from high school begin their curricula with the core engineering program. The primary objective of this program is to provide students with a liberal education and to develop a broad scientific and technical foundation for their future specialization. This predisciplinary-specific program usually extends through the third semester but may extend into the third academic year. During this phase, the primary focus is on the foundations of engineering as a unified field. The foundation in mathematics, physics, chemistry, and biology, combined with the specified engineering sciences (e.g., strength of materials or thermal-fluids, etc.) satisfies basic technical knowledge requirements without regard to the intended field of specialization. In the humanities and social sciences area, courses not only enrich the student as an individual but also provide the perspective professionals need to make decisions that will affect society. The course Introduction to Engineering Design is intended to enhance the student's ability to apply knowledge resourcefully to resolve engineering problems.

The electives within the core engineering program, together with the required basic content, give each student the opportunity to refine his or her goals and develop a broad and solid foundation. Elective

courses also allow undeclared students to sample professionally oriented courses from several curricula so as to make a more enlightened choice of major. A student can also choose electives to provide a broader base or use them to focus on a particular field at an early stage. An imaginative student, with faculty counsel, can develop any number of creative study programs. It is also possible to major in one branch of engineering and obtain a concentration in a second branch.

Students need not begin specializing in a particular area until the fourth semester of study. However, when choosing electives, students must consider that each engineering discipline requires certain courses be taken earlier as field (or discipline) prerequisites.

To provide proper guidance, each student is assigned a faculty adviser who is knowledgeable in core engineering matters and can help the student plan a program to best meet his or her educational and career objectives. Once a student identifies a specific curriculum to pursue, a new adviser, who is particularly aware of the opportunities for advanced study in this area, is assigned.

The combination of the core engineering program with the subsequent discipline-specific courses provides a coherent yet flexible curriculum that allows students to obtain an engineering education at all levels in multiple focus areas. The overall School of Engineering program is structured to permit students to select plans of study that fit their individual goals, aptitudes, and interests. It also enables students to enter and leave at points most appropriate to their individual plans and to facilitate entrance at intermediate levels in the undergraduate and graduate programs.

All elements of the curricula, including both core and discipline-specific courses, are under continuous review to ensure the application of new pedagogues and teaching methods and the introduction of courses covering the latest technological and computing and analysis advances. Topics such as quality, ethics, cultural sensitivity, safety, environmental impact, and contemporary issues related to science and engineering, are constantly integrated into curricula. Additionally included in Rensselaer engineering curricula is the topic of entrepreneurship. Through these efforts, Rensselaer ensures that leadership, interpersonal communications, teamwork, problem formulation, system synthesis, critical thinking, and problem-solving skills are practiced and enhanced.

To provide a clear picture of what prospective engineering students can expect in their first two years at Rensselaer, the core engineering program proceeds as follows:

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1300	Engineering Processes ^{1,2} or	
ENGR-1200	Engineering Graphics and CAD ¹	1	ENGR-1310	Intro. to Engineering Electronics ²	1
MATH-1010	Calculus I.....	4	MATH-1020	Calculus II.....	4
CHEM-1100	Chemistry I.....	4	PHYS-1100	Physics I.....	4
	Hum. or Soc. Sci. Elective.....	4		Science Elective.....	4
				Hum. or Soc. Sci. Elective.....	4

Second Year

Fall		Credit hours	Spring		Credit hours
MATH-2400	Intro. to Differential Equations.....	4	ENGR-2040	Intro. to Engineering Design (with Professional Development I).....	4
PHYS-1200	Physics II.....	4		Engineering Elective.....	4
	Engineering Elective.....	4		Engineering Elective.....	4
	Hum. or Soc. Sci. Elective.....	4		Engineering Elective.....	4
CSCI-1190	Beginning C for Engineers ³	1		Hum. or Soc. Sci. Elective.....	4

¹ These required courses may be taken in either order.

² Depending on major.

³ Excused for students taking CSCI-1100.

Special Undergraduate Opportunities

Undergraduate Research Experience

At Rensselaer, involving undergraduates in real-world engineering research is of paramount importance. Through the Undergraduate Research Program (URP), described in the Educational Resources and Programs section of this catalog, undergraduates work directly with faculty and/or graduate students on projects requiring critical inquiries. These studies involve exciting areas of leading-edge technological research and have the potential to result in groundbreaking discoveries. Involvement in undergraduate research can be arranged strictly for the experience, for credit, or for pay. Students apply through direct contact with faculty seeking students via Web site or campus advertisements.

Cooperative Education

By carefully structuring their programs and taking courses during the summer, some students may augment their academic course work with work experience through the Cooperative Education program. Studies and work assignments are scheduled after consultation with their curriculum adviser. Through careful planning and effective use of summer courses, some co-op students complete their academic program in four years. Some delay graduation for a full academic year to obtain additional work experience. Additional information on Rensselaer's Cooperative Education Program can be found in the Student Life section of this catalog under CareerDevelopment Center.

Study Abroad/Exchange Programs

Rensselaer's School of Engineering is embarking on a new program that will offer the opportunity for all qualified Engineering undergraduates, beginning with the Class of 2010, to participate in an international academic experience abroad. It is intended that this exchange program will allow students to spend one semester, preferably in the third year of undergraduate studies, studying at an engineering school outside of the United States. The schools chosen for this new program will be renowned in the field of engineering education, will teach in English, and be willing to exchange undergraduate engineering students with Rensselaer. Students interested in this program must demonstrate superior academic records, maturity, and a willingness to fully participate in this exchange program. This new program will be strongly recommended for all Engineering students. 25% of the Class of 2010 will be admitted to this option, 50% of the Class of 2012, 75% of the Class of 2014, and all juniors in the Class of 2016 and thereafter.

At the present time, Rensselaer's School of Engineering advocates a voluntary international experience as an ideal means to promote a broad-based engineering education, develop the "citizen engineer," and provide undergraduate students with a global perspective. To facilitate such opportunities, the School has helped formulate and actively participates in the Global Engineering Education Exchange (Global E³) program. Oriented primarily to undergraduate students, this program offers them the chance to spend one or two semesters at an international university which could be followed by an industrial internship in that country. Preferred timing for this experience is the junior year, and students normally apply in the fall or spring of their sophomore year.

Application involves completing forms regarding required courses or desired electives. The Institute for International Education, which administers this program, matches the student to a participating university based on that student's educational discipline requirements, cultural experience, and language background. The student continues to pay tuition at the home institution (Rensselaer) and continues to be covered by financial aid mechanisms, insurance, etc. However, the student pays room and board to the host institution. Consequently, except for travel expenses, students participating in this program should incur no additional costs.

Global E³ offers students the chance to study and learn in the native language of the host country. Such opportunities, for example, are available in France, Germany, Italy, Spain, and Austria. Additional opportunities allow students to pursue foreign study opportunities at universities where the courses are presented and taught in English. These include the Technical University of Denmark, Budapest University of Hungary, and universities in the United Kingdom, Finland, Korea, Singapore, and Japan, among others. As a result, while students may benefit from knowledge of a foreign language, it is not a requirement for participation in this program. Refresher language instruction in French and German is usually given in the summer preceding the fall semester for those who have prior language experience and will be studying in the foreign language.

Approximately 30 U.S. universities and over 75 universities in the rest of the world participate in the Global E³ program. Included among these nations are: Australia, China, Austria, Denmark, Finland, France, Germany, Hungary, Italy, Japan, Korea, Mexico, Singapore, Spain, Sweden, and the United Kingdom. People interested in the program should contact Professor Lester A. Gerhardt, Associate Dean and Vice Provost, at (518) 276-6203 or via e-mail at gerhal@rpi.edu. The program's Web site can be found at <http://www.iie.org/pgms/global-e3>.

Detailed information regarding the launch of our new and expanded international program will be forthcoming. Additional opportunities designed for the Rensselaer population in general are also available. Information on these opportunities can be found in the Educational Programs and Resources section of this catalog.

Overview of Graduate Programs

The School of Engineering offers four graduate degrees through which students may achieve these objectives. These include the Master of Science (M.S.), Master of Engineering (M.Eng.), Doctor of Engineering (D.Eng.), and Doctor of Philosophy (Ph.D.) degrees.

Master's Programs

Both the M.S. and M.Eng. degree programs focus on engineering fundamentals at advanced levels, and both include significant elective opportunities that permit students to individualize their study plans. Either program provides an excellent basis for further graduate work in engineering, and neither includes a foreign language requirement.

The Master of Engineering program is designed primarily for students preparing for professional practice and does not require a thesis. Admission is based on the student's demonstration of adequate preparation and competence. Applications for admission should be transmitted to the Office of Graduate Education. Note that many students complete a Master of Engineering and then pursue a Ph.D.

The Master of Science program encompasses diverse educational needs and is designed primarily for students intending to obtain a Ph.D. degree. Admission requires a baccalaureate degree in an area appropriate to the individual's proposed plan of graduate study and could conceivably be outside the field of engineering. Those who do not have a B.S. in Engineering, however, may be required to complete some extra course work that does not qualify for graduate credit. Depending on the department in which the degree is being pursued, a thesis may be required.

Doctoral Programs

A doctoral student formally affiliates with the department where activities most closely relate to his or her advanced study goals. However, the range of inquiry may cut across department and school lines, so that research opportunities are extremely broad, and students can pursue highly individualized programs. There are no foreign language requirements.

The Doctor of Engineering degree is characterized by the special nature of the thesis. Thus the student, working with an adviser, proposes an engineering problem of substance and develops a solution. The student must demonstrate ability to apply scientific principles to meet engineering needs, with due regard to social and economic factors and within a reasonable time constraint. The presentation and defense of his or her conclusions before a doctoral subcommittee and guests serves as the final examination for the degree.

The Doctor of Philosophy program is the traditional degree with a thesis that involves substantial original research. The program follows the general rules of the Office of Graduate Education.

Biomedical Engineering

Department Head: Natacha DePaola

Department Home Page: <http://www.bme.rpi.edu/>

Biomedical engineers are typically involved in research and design. They discover new knowledge that they apply to designing new engineering devices and systems for the fields of medicine and biology. Among the devices that biomedical engineering (BMED) has produced are noninvasive body imaging systems, critical-care monitoring instruments used in intensive care units, and a wide spectrum of implants, such as artificial joints, oral implants, and vascular grafts, all of which are used to replace diseased tissues. With new discoveries related to stem cells, genomics, and proteomics, BME is becoming increasingly involved in cellular and molecular biology for basic research and design of new devices and technologies. For instance, many biomedical engineers are helping to advance the new field of tissue engineering. In this capacity, they use basic knowledge about the cellular/molecular processes of tissue regeneration to help design replacement tissues and organs. At Rensselaer, a key focus is functional tissue engineering, which encompasses the biology and engineering necessary to understand, characterize, synthesize, and shape the requisite mechanical and functional behavior of living tissues.

Founded upon a strong engineering base, the BMED curriculum combines significant life science content with courses that bring engineering solutions to medical needs. BMED students may select a mechanical or materials concentration to develop knowledge and skills in cell and tissue engineering or implant design.

Research Innovations and Initiatives

Cell and Tissue Engineering

Mammalian cell cultures are used to study systems of biomedical interest at the cell and molecular level. Experimental projects in progress include (1) investigations of the mechanisms of osteoblast interactions with orthopedic/dental implant materials; (2) structure and biochemistry of the cell/biomaterial interface; (3) effects of mechanical stresses on cellular function, morphology, and structure; (4) the development of engineering tissues to repair or replace damaged tissues including the mechanistic understanding of neural injury and repair. Theoretical approaches are used in modeling proliferation of anchorage-dependent, contact-inhibited cells, and in quantifying morphological responses of cells to mechanical forces.

Computational Bioengineering

The level of complexity inherent in the study of human systems such as musculoskeletal or cardiovascular systems frequently dictates the need for numerical solution methods. Rensselaer is developing and applying high-performance computational methods to the study of diarthrodial joint mechanics, cardiovascular mechanics, dental mechanics, and imaging. Projects involving the development of computational methods for bioengineering applications are done in collaboration with Rensselaer's Scientific Computation Research Center, as well as the Center for Subsurface Sensing and Imaging Systems (CenSISS).

Implantable Sensors

Ongoing research includes the design, packaging and integration of novel sensors into chronic implants to facilitate direct experimental measurement of physical parameters in vivo in (1) oral implants, (2) fracture fixation devices, and (3) spinal implants.

Orthopaedic Engineering

In an aging individual, musculoskeletal well-being is a key factor that contributes towards quality of life. Continuing research includes cellular and tissue-level approaches to (1) identifying changes in the biological and mechanical characteristics of skeletal tissues with emphasis on aging and osteoporosis; (2) developing microenvironments conducive to regeneration of lost or damaged bone matrix; (3) characterizing the mechanisms that causes degeneration of the intervertebral disc in response to loading; and (4) understanding the biomechanical effects of spine implants and tissue substitutes. Current research areas include biology and mechanics of hard tissue, cellular control of tissue growth and development, mechanobiology of skeletal tissue regeneration, fatigue fractures of long bones, mechanism of sclerosis of subchondral bone, and biomechanics of fracture fixation.

The Tissue Interface

In oral/maxillofacial surgery, orthopedic surgery, and tissue engineering, events at the bone-implant interface ultimately determine clinical implant performance. All such interfaces transmit loads, so interfacial biomechanics and biomaterials become extremely relevant. Continuing projects include (1) characterization of implant biomechanics, and (2) assessment of bone biology at loaded versus unloaded bone-implant interfaces. New aspects of these projects include digital image-based strain analysis of interfaces and cellular/molecular-level approaches to understand interfacial bone healing and remodeling under the influence of interfacial biomechanics and biomaterials.

Other Research

Biomedical engineering research at Rensselaer involves three schools within the Institute and interactions with Albany Medical College, the University of Pennsylvania, Columbia University, Université de Montreal, Johns Hopkins, Stanford University, Union College, the Center for Tissue Integrated Prostheses (Spokane, Wash.), and several other hospitals.

Faculty*

Professors

Bizios, R.—Ph.D. (Massachusetts Institute of Technology); cellular bioengineering, cell/biomaterial interactions, biomaterials.

Brunski, J.B.—Ph.D. (University of Pennsylvania); dental biomechanics and implants, bone healing at interfaces, biomaterials.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting.

DePaola, N.—Ph.D. (MIT-Harvard Medical School); biofluid mechanics, cellular bioengineering (Department Head).

Roysam, B.—D.Sc. (Washington University); electrical, computer, and systems engineering; intelligent imaging at low SNR; parallel computation; biomedical applications.

Spilker, R.L.—Sc.D. (Massachusetts Institute of Technology); computational mechanics and biomechanics.

Stenken, J.A.—Ph.D. (University of Kansas); bioanalytical chemistry.

VonMaltzahn, W.W.—Ph.D. (University of Hannover, Germany) bioinstrumentation, physiological measurements and modeling.

Associate Professors

Jansen, K.—Ph.D. (Stanford University); computational mechanics, parallel computing, computational fluid dynamics.

Vashishth, D.—Ph.D. (University of London, UK); orthopedics biomechanics, hard tissue biology (aging and osteoporosis), sports medicine (stress fractures and running injuries), skeletal tissue regeneration.

Xu, G.X.—Ph.D. (Texas A&M University); environmental health physics, health and medical physics, Monte Carlo simulations, anatomical modeling, biomedical use of radiation.

Assistant Professors

Ledet, E.—Ph.D. (Rensselaer Polytechnic Institute); in vivo sensor development, degenerative diseases of the spine, biomechanics of fracture fixation.

Plopper, G.—Ph.D. (Harvard University Medical School); extracellular matrix and tissue engineering.

Stegemann, J.P.—Ph.D. (Georgia Institute of Technology); cell and tissue engineering, vascular biology, extracellular matrix biology.

Thompson, D.M.—Ph.D. (Rutgers University); tissue engineering (neural), neural cell and tissue engineering, neural biology, MEMS/microfluidics.

Yacizi, B.—Ph.D. (Purdue University); inverse problems in biomedical imaging, tomography, diffuse optical tomography, biomedical optics, free space optical communications, ultrasonics, statistical pattern recognition theory and application.

Research Professor

Newell, J.C.—Ph.D. (Albany Medical College); cardiopulmonary physiology, systems modeling, impedance imaging.

Research Assistant Professors

Mehta, S.—Ph.D. (University of Texas Southwestern Medical Center); biotechnology management and entrepreneurship.

Affiliated Faculty

Cheney, M.—Ph.D. (Indiana University); professor of mathematical sciences; applied mathematics, differential equations, mathematical computed tomography.

Isacson, D.—Ph.D. (New York University); professor of mathematics and computer science; electric current computed tomography.

Adjunct Faculty

Bowser, S.S., Jr.—Ph.D. (University at Albany); cell structure and function, particularly cell motility and cytoskeleton-membrane interactions, effects of mechanical forces on cell physiology, biology of benthic foraminifera.

Del Vecchio, P.J.—Ph.D. (Fordham University); biology, vascular endothelium.

- Flaherty, L.**—Ph.D. (Cornell University Medical College); molecular genetics; mammalian genetics.
Director, Genomics Institute, Wadsworth Center of the NYS Dept. of Health.
- Metzger, D.**—Ph.D. (University of Illinois at Chicago); regulation of immunity, mucosal immunology, immune response to xenogeneic tissue implants.
- Rangert, B.**—Ph.D. (Chalmers Institute of Technology); dental implants, biomaterials, biomechanics.
- Singer, H.**—Ph.D. (University of Virginia); vascular smooth muscle cell biology, calcium/calmodulin-dependent protein kinases, intracellular regulation of smooth muscle contractility.
- Turner, J.N.**—Ph.D. (State University of New York, Buffalo); biophysics, anatomic pathology, quantitative light microscopy.
- Emeritus Faculty**
- Ostrander, L.E.**—Ph.D. (University of Rochester); information processing, biomedical signal analysis, human factors in medical equipment design.
- Roy, R.J.**—M.D. (Albany Medical College), D.Eng.Sci. (Rensselaer Polytechnic Institute); systems physiology, digital signal processing, pattern recognition.
- Zelman, A.**—Ph.D. (University of California, Berkeley); membrane transport phenomena, food processing.

Undergraduate Programs

Objectives of the Undergraduate Curriculum in Biomedical Engineering

Graduates of the Department of Biomedical Engineering will:

- Have a solid foundation in mathematics and computation and in the biological and physical sciences.
- Function in a technically competent manner in applying the engineering problem-solving skills of analysis, modeling, and simulation to current problems in medicine and biology.
- Have the ability to design biomedical products, processes, and systems.
- Have specialized technical expertise that applies to industrial, academic, or other careers in biomedical engineering.
- Have strong written and oral presentation skills, as well as the ability to lead and contribute to multidisciplinary teams in industrial, academic, and clinical environments.
- Have a broad educational background, including the study of the humanities and social sciences, with an emphasis on ethics and social responsibility.
- Understand the importance of life-long learning.

Students may achieve these objectives through completion of the baccalaureate program leading to the B.S. degree. To ensure selection of the appropriate concentration and courses to meet individual interests and goals, students should consult their academic adviser as early as possible.

Baccalaureate Program

In lieu of the general core engineering program presented earlier, students who identify biomedical engineering as their discipline may follow the program outlined below. This curriculum requires a minimum of 128 credits.

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1200	Engineering Graphics and CAD	1
CHEM-1100	Chemistry I.....	4	MATH-1020	Calculus II	4
MATH-1010	Calculus I.....	4	PHYS-1100	Physics I.....	4
BMED-1330	Intro. to BME ¹	1	BIOL-1010	Hum. or Soc. Sci. Elective ²	4
	Hum. or Soc. Sci. Elective ²	4		Intro. to Biology.....	4

Second Year

Fall		Credit hours	Spring		Credit hours
CSCI-1190	Beginning C Prog. for Engrs.	1	BMED-2200	Dynamic Systems for Biomedical Engineering	4
PHYS-1200	Physics II.....	4	ENGR-2050	Intro. to Engineering Design	4
MATH-2400	Intro. to Differential Equations	4	ENGR-2600	Concentration I.....	4
	Hum. or Soc. Sci. Elective ²	4		Mod. & Analysis of Uncertainty	3
ENGR-1600	Materials Science for Engineers.	4			

Third Year

Fall		Credit hours	Spring		Credit hours
BIOL-4290	Human Physiological Systems.....	4	BMED-4500	Advanced Systems Physiology	4
	Concentration II.....	4		Concentration IV	3
	Concentration III	4		Concentration V.....	4
	Hum. or Soc. Sci. Elective ²	4		Free Elective I ⁴	3
			Professional Development II ³	2	

Fourth Year

Fall		Credit hours	Spring		Credit hours
BMED-4010	Biomedical Engineering Lab	4	BMED-4600	BME Design ⁶	3
	Concentration VI	3-4		Free Elective IV	3
	Free Elective II ⁴	3		Concentration VII	3-4
	Free Elective III ⁴	3		Hum. or Soc. Sci. Elective ²	4
BMED-4961	Biomedical Product Design	3	ENGR-4010	Professional Development III ⁴	1
	& Devel. ⁵				

The total credit hours for the degree is 128–130.

¹ ENGR-1330 or ENGR-1300 may be taken in the first or second term.

² Placement of humanities and social science electives can be varied with free electives. The courses counted as free electives must show a minimum of twelve (12) credit hours.

³ Professional Development II will be fulfilled from a published list at the start of each semester and can be taken either semester. Professional Development III can be taken either semester of the senior year. Professional Development I is part of ENGR-2050.

⁴ The minimum total credit hours of free electives is twelve (12), with no restrictions on the included number of 3- and 4-credit hour courses.

⁵ Co-op students can take Commercializing BME Technology (a Spring course; BMED-4xxx) in lieu of this course.

⁶ Capstone writing-intensive course.

BMED Concentration Options – Seven courses required

BMED Required Courses – Materials Concentration: (Required credits: 19 Credits)

BMED-2100	Biomaterials Science and Engineering (4CR) (S2)
ENGR-2250	Thermal and Fluids Engineering I (4CR) (F3)
BMED-4540	Biomechanics (4CR) (F3)
BMED-4240	Tissue-Biomaterials Interaction (3CR) (S3)
MTLE-2100	Structure of Engineering Materials (4CR) (S3)

BMED Elective Courses – Materials Concentration (Choose two; Required Credits 6)

BMED-4650	Introduction to Cell and Tissue Engineering (F)
BMED-4962	Mechanobiology (S, Odd years)
BMED-4963	Biology and Engr. of the Extracellular Matrix (S, Even years)
BMED-4964	Biomems (S)
MTLE-4100	Thermodynamics of Materials (F)
MTLE-4030	Introduction to Glass Science (F)
MTLE-4050	Introduction to Polymers (F)
MTLE-4250	Properties of Engineering Materials II (S)
MTLE-4630	Composites Laboratory (S)

BMED Required Courses – Mechanics Concentration (Required credits: 19 Credits)

BMED-2961	Biomaterials Science and Engineering (4CR) (S2)
ENGR-2250	Thermal and Fluids Engineering I(4CR) (F3)
BMED-4540	Biomechanics (4CR) (F3)
BMED-4240	Tissue-Biomaterials Interaction (3CR) (S3)
ENGR-2530	Strength of Materials (4CR) (S3)

BMED Elective Courses – Mechanics Concentration (Choose two Required Credits 6):

BMED-4650	Introduction to Cell and Tissue Engr. (F3)
BMED-4962	Mechanobiology (S, Odd years)
BMED-4965	Biomechanics of Hard Tissues (F, Odd years)
BMED-4966	Biomechanics of Soft Tissues (F, Even years)
ENGR-2090	Engineering Dynamics (4CR) (S)
MANE-4240	Introduction to Finite Elements (F&S)
MANE-4030	Elements of Mechanical Design (F&S)
MANE-4610	Vibrations (F)
MANE-4130	Analysis and Design of Composite Structures (S)
MANE-4670	Mechanical Behavior of Materials I (F)

Humanities and Social Sciences Electives

In this area, electives are based on the Institute and School of Engineering requirements. Students are urged to select humanities and social science sequences with adequate breadth and depth in subject areas. Students desiring minors in humanities or social sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Minor Programs

The Department of Biomedical Engineering offers a minor in biomedical engineering for undergraduates majoring in other engineering and science fields. The selection of courses must have the prior approval of the department and must form a coherent program. Below is a list of suggested courses for a minor in biomedical engineering.

For Mechanical or Materials Engineering Majors

BMED-4010	Biomedical Engineering Laboratory	BMED-4540	Biomechanics
BIOL-4290	Human Physiology Systems	BMED-4240	Tissue-Biomaterial Interactions
BMED-4500	Advanced Systems Physiology		

Graduate Programs

The department offers programs leading to M.S., D.Eng., and Ph.D. degrees. Persons seeking admission to any of these graduate degree programs in biomedical engineering should have their Graduate Record Examination (GRE) aptitude test scores sent to Graduate Admissions Office. Applicants who cannot take the test should attach an explanation to the application. Submission of the GRE advanced test scores is also recommended. For further information on the GREs, write to Graduate Record Examinations, Box 955, Princeton, NJ 08541.

Master's Programs

Rensselaer requires completion of at least 30 credit hours (with satisfactory grades) beyond the bachelor's degree. At least 15 of these credit hours must have suffix numbers 6000–6990.

Master of Science

The Biomedical Engineering M.S. degree can be obtained with or without a thesis. The latter option is recommended for students who do not plan further graduate studies. The thesis option is advised for students who plan to obtain a higher graduate degree. The master's thesis should contribute new knowledge to the field of study.

Students pursuing either M.S. option must complete a minimum of 30 credits. In consultation with their adviser, they must develop a Plan of Study that satisfactorily meets Institute requirements, core concentration requirements, and recommended technical electives. For students completing a thesis, at least 24 credits must be met in these requirements.

Concentrations

At the M.S. level in Biomedical Engineering, programs of study fall into two different concentration areas:

Biomaterials

Engineering applications for the design of prosthetic devices such as implants or tissue-engineered constructs require sophisticated knowledge of the structure, properties, and behavior of a wide range of materials—metals, ceramics, glasses, polymers, composites, and biological materials. Implant design and the new field of tissue engineering involve a working knowledge of material properties, tissue-biomaterial interactions, and biocompatibility.

Biomechanics

Mechanics has helped solve problems involving cell physiology, blood flow, skin rheology, bone mechanics, load-bearing prostheses design, joint lubrication methods, and countless other items of interest in medicine. Continuum mechanics, finite element analysis, strain gauge techniques, model analysis techniques, and micromechanics are some of the methods used to attack these problems in biomechanics.

Biomedical Engineering Requirements

In addition to the Biomedical Engineering core requirements, students must also meet the concentration and elective requirements.

Core Requirements	Credit hours
BMED-4010 Biomedical Engineering Lab I	4
BMED-4500 Advanced Systems Physiology*	4
Biomaterial Concentration requirements	Credit hours
DSES-6020 Design of Experiments (or an equivalent course)	3
Biomechanics Concentration requirements	Credit hours
BMED-4540 Biomechanics	3
DSES-6020 Design of Experiments (or an equivalent course)	3

Technical electives can be chosen from BME courses and from other engineering and science courses at Rensselaer in consultation with the adviser.

Doctoral Programs

Matriculation into the doctoral program is based upon prior demonstration of a high level of academic achievement in graduate and/or undergraduate work. Advanced study and research are conducted under the guidance of a faculty member of the Department of Biomedical Engineering and an interdisciplinary committee. Usually 54 credits of formal courses are required in addition to the residency and thesis requirements. These requirements are formalized in a Plan of Study that is prepared in consultation with the research adviser and doctoral committee.

Technical electives can be chosen from BME courses and from other engineering and science courses at Rensselaer in consultation with the adviser.

Course Descriptions

Courses directly related to all Biomedical Engineering curricula are described in the Course Description section of this catalog under the department codes BMED, CHME, ECSE, MTLLE, and MANE.

Chemical and Biological Engineering

Department Head: Steven M. (Acting)

Director, Industrial Liaison Program: E. Bruce Nauman

Department Home Page: <http://www.eng.rpi.edu/dept/chem-eng/>

The chemical conversion of resources into new, more useful forms has been the traditional concern of chemical engineering. In recent years, chemical engineering has played a major role in high technology advances in biotechnology and novel materials processing. In addition, a critical concern with the depletion of resources has developed leading to increased efforts to conserve, recycle, and find environmentally friendly alternatives.

The major educational objective in the Howard P. Isermann Department of Chemical and Biological Engineering is to prepare students to enter their engineering practice dealing with chemical as well as physical processes to meet the challenges of the future. The curriculum, which builds on chemistry, biology, mathematics, basic sciences, and engineering science, culminates in professional applications in

* New graduate students entering BMED with no previous biological course work can take BMED-4290 as a background course, but in this case, this course is not counted in the credits for the master's or Ph.D. degree.

which theory is tempered by engineering art and economic principles. Through this curriculum, graduates are prepared equally well for professional practice or for advanced study.

Opportunities for creative and satisfying practice in chemical and biological engineering can be found in conception, design, control, or management of processes involving chemical and/or biochemical transformations. These processes range from the more conventional conversion of crude oil into petrochemicals and plastics, to the microbiological transformation of hardwood chips into specialty alcohols, or to the creation of semiconductor devices from silicon wafers. Diverse career choices exist not only in the chemical industry, but in virtually all processing industries, including agricultural, biotechnology, chemical, food, nuclear, semiconductor processing, and environmental operations. By emphasizing basic principles, the program prepares its graduates for positions spanning the spectrum of activities from research and development, to process and project engineering, to production, or to technical marketing.

Research and Innovation Initiatives

Biochemical and Biomedical Engineering

Research projects in biochemical engineering emphasize biocatalysis, bioseparations, and metabolic engineering. Fundamental and applied aspects of enzyme technology, mammalian cell culture, membrane sorption and separation, displacement chromatography, and salt-induced precipitation are important areas of focus. New designs involving aqueous and nonaqueous enzyme technology are being developed, as are new types of membrane-entrapped-enzyme and animal-cell-suspension reactors, which are being built, tested, and analyzed. Metabolic engineering processes are being used to develop high-rate bacterial fermentations and overproducing hybridoma cultures for producing chemical intermediates and monoclonal antibodies, respectively. Control theory of biological processes and an optical biosensor for metal detection are also being pursued. Projects in biomedical engineering involve the design of polymeric inhibitors of bacterial toxins and viruses, and the use of microfabrication tools to modulate the interaction of mammalian cells with their environment for applications in tissue engineering.

Separation and Bioseparation Processes

Research projects in separation and bioseparations employ fundamental concepts for solving applied problems in the biological and environmental fields. Current projects emphasize interactions of proteins with synthetic membranes and chromatographic media, high throughput screening, combinatorial and computational chemistry, spectroscopy, chip technology, proteomics, modification of polymeric surfaces for bioseparations and environmental applications, and the recovery of proteins from complex biological solutions using fusion affinity adsorption, pressure-driven membrane processes, displacement chromatography and expanded-bed adsorption.

Molecular Simulations

Monte Carlo and molecular dynamics simulations are being used in combination with statistical mechanical theories to understand thermodynamics, structure, and kinetics of biomolecules in aqueous solutions. Special emphasis is placed on understanding and relating water structure near different solutes and in different environments to resulting interactions (e.g., hydrophilic and hydrophobic interactions). Molecular simulation techniques are also being applied to polymeric systems to understand penetrant solubility and diffusivity in polymers.

Advanced Materials

Research interests are centered on developing and understanding the phenomena involved in producing advanced materials for the optical, electronic, and allied industries. Thermodynamic, transport, and chemical processes governing the formation and subsequent behavior of these materials are under active

investigation. Research areas include modeling and optimizing CVD-reactor-system designs for producing high-efficiency, epitaxial layers economically in an environmentally sound manner, and developing nonlinear and electro-optic inorganic and organic materials for switching and memory applications. Additional research areas are understanding phenomena involved in the production and use of microlens arrays, wave-guide lasers, and determining the composition, property, and structure relationships of crystalline and glassy materials.

Interfacial Phenomena

Problems under investigation include interfacial resistance to mass transfer and the interaction between surface forces and interfacial convection. Work in the interfacial area is concerned with heat, mass, and momentum transfer in multicomponent, ultrathin, liquid films. Research includes studies on condensation and evaporation in the contact line region, distillation from ultrathin films, lubrication, surface-tension-driven instabilities in atomically clean liquid metals, pattern formation in dendritic growth, protein-solid interaction, and the design of biocompatible surfaces.

Polymers

A large polymer research program focuses on polymer reaction engineering including devolatilization and heat transfer. Current work emphasizes bulk polymerizations in tubular reactors and segregation phenomena in stirred tank reactors. Under study are ways of enhancing heat transfer to fluids in laminar flow and the application of polymer devolatilization technology to unconventional substances. The recovery of commingled scrap plastics by selective dissolution is a major activity. Other active areas include structure-property relationships, rheology, extrusion, and a large interdisciplinary program on biocatalysis in polymer synthesis and modification.

High-Temperature Kinetics

The development of more efficient, less polluting, combustion systems, requires accurate chemical kinetic input data on individual reactions over large temperature ranges. Rensselaer is pioneering the development of experimental techniques for obtaining such data. This work includes design, construction, experimentation, and the generation of data for use by reaction system modelers. Both fast-flow thermal and pseudostatic photochemical systems are used. Various light sources, such as lasers, combined with electro-optical detection techniques are employed to determine the time history of reactants. Larger reactants and products are observed mass spectrometrically. Microcomputers are used for experimental control and data handling. In some work, the light-emitting and electrical-charge generation aspects of reactions are also investigated. In addition to combustion, this work is important to technological fields, such as semiconductor processing, metals refining, and optical fiber and carbon black manufacturing, as well as models of the atmosphere. A better understanding of the temperature dependence of reaction rate coefficients is a significant result of this work.

Process Control and Design

A major focus of this research is the development of realistic, robust control strategies for multivariable chemical processes having parameter and process uncertainties. Such strategies are created to exploit the dynamic properties inherent in the systems. Integration of the modeling, design, and control of specialty chemical and pharmaceutical processes is of particular interest.

Heat Transfer

Topics of interest include free convection stability, forced convection (particularly in laminar flow systems), fluid-to-particle heat transfer in fluidized and spouted beds, and boiling. Studies on heat and mass transfer at interfaces are also under way.

Thermodynamics

Activities include molecular simulation, the analysis and correlation of phase-equilibrium data, the development and evaluation of fluid-phase equations of state, and the study of topics in solution thermodynamics.

Mass Transport

Research is in progress on simultaneous heat and mass transfer in porous media; the effects of interfacial phenomena on mass transfer; diffusion and mixing in laminar flow systems; transient dispersion processes in capillaries, porous media and open channels; and crystal growth phenomena.

Fluid Mechanics

Projects in this area involve the mechanics of fluidized beds, spouted beds, bubbles, low Reynolds number hydrodynamics, kinetic theory, two-phase flow, and surfactant behavior in organic-aqueous systems.

Interdepartmental Research

Several research areas involve participation and cooperation with other departments. Such areas include polymer studies with the Materials Science and Engineering and Chemistry Departments, fermentation and other biochemical research with the Biology Department, studies in fluid mechanics with the Mathematics Department, polymer membrane fabrication with the Chemistry Department, and research on lubrication and other interfacial phenomena with the Mechanical Engineering Department. Research into state-of-the-art design and optimization of CVD reactors for semiconductor production is conducted jointly with the Center for Integrated Electronics. Additional information on research in these areas is found in the catalog sections for those departments.

Research Related Facilities

The department maintains extensive research and instructional laboratories which house myriad special and unique equipment developed for specific studies, as well as extensive analytical and optical instrumentation, minicomputers, and microcomputers. Major instrumentation such as a GC/mass spectrometer, an X-ray fluorescence analyzer, an ion chromatograph, HPLC systems, and a laser zee particle characterization system make Rensselaer's laboratories one of the most comprehensively equipped university centers for research in the areas described above. The Howard Isermann Biochemical Engineering Laboratory was established in the department exclusively for conducting biochemical engineering research. The department research programs also use a number of major university facilities including the electron optics laboratory and the polymer laboratories in the Materials Research Center.

Faculty*

Professors

Belfort, G.—Ph.D. (University of California, Irvine); membrane sorption and separations engineering, biocatalysis, biosensors, magnetic resonance flow imaging.

Bequette, B.W.—Ph.D. (University of Texas, Austin); chemical process modeling, control, and optimization; biomedical and drug infusion systems.

Cale, T.S.—Ph.D. (University of Houston); microelectronic materials processing and simulation.

Coppens, M.-O.—Ph.D. (University of Gent, Belgium), reaction engineering, nanomaterials, nano-biotechnology, mathematical modeling (chaos and fractals), and nature inspired chemical engineering.

Cramer, S.M.—Ph.D. (Yale University); biochemical engineering, chromatographic separations.

Dordick, J.S.—Ph.D. (Massachusetts Institute of Technology); biochemical engineering, enzyme technology, polymer chemistry, bioseparations.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting.

Garcia, A.—Ph.D. (Cornell University); theoretical and computational aspects of biomolecular dynamics.

Garde, S.S.—Ph.D. (University of Delaware); molecular simulation.

Glicksman, M.E.—Ph.D. (Rensselaer Polytechnic Institute); transport phenomena of crystal growth.

Hirsa, A.—Ph.D. (University of Michigan); fluid mechanics, experimental gas dynamics.

Kumar, S.K.—Ph.D. (Massachusetts Institute of Technology) Synthetic and bio-polymers, nano composites and nanomaterials.

Lahey, R.T., Jr.—Ph.D. (Stanford University); two-phase flow and boiling heat transfer.

Nauman, E.B.—Ph.D. (University of Leeds, England); reaction engineering, dispersion theory, laminar heat transfer.

Plawsky, J.L.—Sc.D. (Massachusetts Institute of Technology); optical, nonlinear and electrooptic, crystalline, and glassy materials.

Associate Professor

Kane, R.S.—Ph.D. (Massachusetts Institute of Technology); biomedical engineering, polymers, surfaces, nanomaterials.

Assistant Professors

Martin, L.L.—Ph.D. (University of California, Los Angeles) process systems engineering, design for waste minimization and pollution prevention.

Sharfstein, S.T.—Ph.D. (University of California, Berkeley); biochemical engineering, mammalian cell culture.

Distinguished Research Professors

Fontijn, A.—D.Sc. (University of Amsterdam, Netherlands); combustion, high-temperature kinetics, gas phase reactions, atmospheric chemistry.

Gill, W.N.—P.E., Ph.D. (Syracuse University); transient dispersion processes, reverse osmosis systems, crystal growth phenomena, surface-tension-driven flow.

Wayner, P.C., Jr.—Ph.D. (Northwestern University); heat transfer, interfacial phenomena.

Adjunct Faculty

Belfort, M.—Ph.D. (University of California, Irvine); molecular biology.

Emeritus Professors

Abbott, M.M.—Ph.D. (Rensselaer Polytechnic Institute); thermodynamics.

Altwickler, E.R.—Ph.D. (Ohio State University); air pollution control, atmospheric chemistry.

Bungay, H.R., III—P.E., Ph.D. (Syracuse University); water resources, biochemical engineering.

Chung, C.I.—Ph.D. (Rutgers University); polymer processing, polymer melt rheology, relaxation behavior in polymer solids.

Littman, H.—Ph.D. (Yale University); fluidization, fluid-particle systems.

Muckenfuss, C.—Ph.D. (University of Wisconsin); kinetic theory, transport phenomena.

Van Ness, H.C.—P.E., D.Eng. (Yale University); thermodynamics.

Undergraduate Programs

Objectives of the Undergraduate Curriculum

Graduates of the Howard P. Isermann Department of Chemical and Biological Engineering will:

- Have a solid background in chemistry, mathematics, basic science, and engineering science.
- Have technical knowledge of fundamental chemical engineering concepts of balance equations, thermodynamics, transport phenomena, chemical reaction engineering, separations processes, and process systems engineering.

- Be able to communicate technical material through written reports and oral presentations.
- Apply chemical engineering principles and economic analysis to the synthesis of chemical processes and products. These complex problems require teamwork and the ability of individuals to serve as leaders and contributors.
- Be prepared equally for professional practice or further graduate study in chemical engineering and biological engineering.
- As with all engineering disciplines, be informed citizens, broadly educated in the humanities and social sciences.

Students may achieve these objectives through completion of either the baccalaureate program leading to the B.S. degree or the professional program leading to the M.Eng. degree. Both programs are described in detail below.

Baccalaureate Programs

The chemical engineering program comprises a minimum of 37 courses, which include three free electives and three area electives: one in advanced chemistry, one in advanced chemical engineering, and one in a nonchemical engineering area. On completion of three years of the baccalaureate program, the student may continue to the fourth year or be admitted to the professional program. While individual variations may be made in the course sequence in consultation with a faculty adviser, all listed courses and elective credits in the curricula must be satisfactorily completed to qualify for the specified degrees. A program outline that indicates required courses and electives is provided below. The complete curriculum totals 128 credit hours.

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1200	Eng. Graphics and CAD ¹	1
ENGR-1300	Engineering Processes ^{1,2}	1	BIOL-1010	Introduction to Biology.....	4
CHEM-1100	Chemistry I.....	4	MATH-1020	Calculus II	4
MATH-1010	Calculus I.....	4	PHYS-1100	Physics I.....	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4

Second Year

Fall		Credit hours	Spring		Credit hours
CHME-2010	Material, Energy, and Entropy Balances.....	4	CHME-2020	Energy, Entropy, and Equilibrium ³	4
MATH-2400	Intro. to Differential Equations	4	ENGR-2600	Modeling and Analysis of Uncertainty	3
PHYS-1200	Physics II.....	4	CSCI-1190	Beginning C Programming for Engineers	1
CHEM-2210	Organic Compounds & Reactions ...	4		Free Elective	4
				Hum. or Soc. Sci. Elective	4

Third Year

Fall		Credit hours	Spring		Credit hours
CHME-4010	Fluid Mechanics and Heat Transfer ..	4	CHME-4020	Heat and Mass Transfer	3
CHEM-4530	Modern Techniques in Chemistry.....	4	CHME-4030	Chemical Process Dynamics and Control.....	4
	Free Elective	4	CHEM-4460	Microscopic Physical Chemistry.....	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4
				Professional Development II ⁴	2

¹ These required courses may be taken in either order.

² May be replaced by ENGR-1310.

³ Includes Professional Development I.

⁴ Choice of STSS-4840 or PSYC-4170

Fourth Year

Fall		Credit hours	Spring		Credit hours
CHME-4040	Chemical Engineering Separations.....	3	CHME-4050	Chemical Process Design	3
CHME-4150	Chem. Eng. Lab. I.....	2		Elective ⁵	2
CHME-4500	Chemical Reactor Design	3	ENGR-4010	Professional Development III	1
	Free Elective	4		Engineering Elective	4
	Chemical Engineering Elective	3		Chemistry Elective.....	4

Electives

As is evident in the above outline, the B.S. program includes several types of electives, three of which are specifically designated. These designated electives are subject to the following constraints:

- The chemistry elective must be in advanced chemistry or in an advanced chemistry-related subject.
- The chemical engineering elective must be in chemical engineering or in an approved, advanced chemical engineering subject.
- The engineering elective cannot be a chemical engineering course; it must be at least 2000-level and contain four credits of engineering topics.

The curriculum clearance officer, who maintains a list of appropriate courses, must approve selection of these three constrained electives. The three free electives are completely unconstrained.

Humanities and Social Sciences Electives

In this area, the electives are based on the Institute and School of Engineering requirements. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Professional Program

Students who, at the end of their third year, apply and are accepted to this program will complete ten additional courses beyond the baccalaureate degree and will be awarded the M.Eng. degree. This program is described in detail below.

Graduate Programs

The Chemical and Biological Engineering Department offers the Master of Science, the Master of Engineering, and the Doctor of Philosophy degrees, each of which is tailored to fulfill the varying educational needs of its graduate students.

All graduate programs offer flexibility. Students are advised to plan programs that use course choices and electives to obtain in-depth studies in one or more specialties of their degree majors. Cross-disciplinary studies using courses offered by other departments or schools at Rensselaer are encouraged.

In addition, all graduate degree programs are arranged individually, and students are encouraged to use electives to conduct intensive studies in one or more subdisciplines or specialties. The M.S. and Ph.D. programs are particularly flexible. However, each student's program must include the following courses:

CHME-6570	Chemical and Phase Equilibria (Fall)
CHME-6610	Mathematical Methods in Chemical Engineering I (Fall)

⁵ Choice of CHME-4160 or CHEM-4170

- CHME-6510 Advanced Fluid Mechanics I (Spring)
- CHME-6640 Advanced Chemical Reactor Design (Spring)

Master’s Programs

The master’s degree represents an intermediate level of academic preparation. It is often the optimal degree for careers in engineering design.

Master of Science

The M.S., which requires a thesis, may be used for professional entry, but is also well suited to students who wish to measure their ability to get a Ph.D. without commitment of extra time beyond that required for an M.S. A special optional master’s program is available for this purpose.

For the M.S., 30 credits of graduate-level studies, including six credits for the thesis, are normally required. However, the thesis requirement may vary from three to nine hours at the discretion of the department. The 24 hours of approved course work must include at least 15 credits of 6000-level courses. A formal thesis defense is not required.

Students who wish to follow the optional master’s program should plan to take the Ph.D. comprehensive examination during their second semester of full-time graduate studies. The examination may be taken a maximum of two times. Passing students may register for an additional three credits of CHME-6990 Master’s Thesis, and formal course work requirements for the master’s degree are reduced to 21 hours. The student also has the option of proceeding directly toward a Ph.D. without completing the master’s thesis. This option will normally reduce the time required for a Ph.D. by about six months. Students who elect to proceed in this manner will receive an M.S. degree, with thesis requirements waived, after two years of satisfactory full-time study and acceptance of the dissertation proposal.

Master of Engineering

The M.Eng. degree involves formal course work only and does not require a thesis. This degree is awarded on completion of 30 credits of course work. For a student with an accredited B.S. degree in chemical engineering, the program includes the following:

	Credit hours
CHME-6510 Advanced Fluid Mechanics I	3
CHME-6570 Chemical and Phase Equilibria.....	3
CHME-6610 Math Methods in Chem. Eng. I.	3
CHME-6640 Advanced Chemical Reactor Design.	3
Electives	18

Of the electives, at least two must be chemical engineering courses and at least two must be nonchemical engineering courses. A feature of this M.Eng. program is the opportunity to concentrate in one of the subspecialties of chemical engineering. These areas include (but are not limited to) biological engineering, process systems engineering, materials engineering, and polymer engineering.

Doctoral Programs

The Ph.D. degree represents the highest level of academic preparation. With it, a student can expect to maintain technical competence and contributions throughout a professional career. It is usually the preferred degree for research and development in industry and government and for teaching.

Within the Chemical and Biological Engineering Department, 90 credits of graduate-level studies, including the dissertation, are required for a Ph.D. The emphasis is on advanced study in a specialty with major focus on the dissertation. A doctoral student must pass a comprehensive examination, prepare a dissertation proposal and the dissertation itself, and present and defend the dissertation.

Course Descriptions

Courses directly related to all Chemical and Biological Engineering curricula are described in the Course Description section of this catalog under the department code CHME.

Civil and Environmental Engineering

Department Head: Thomas F. Zimmie (Acting)

Coordinator of Undergraduate Studies (Civil and Environmental Programs): Simeon Komisar

Coordinator of Graduate Studies (Civil Program): Tarek Adboun

Coordinator of Graduate Studies (Environmental Program): James (Chip) Kilduff

Department Home Page: <http://www.cee.rpi.edu>

Civil and environmental engineers are responsible for providing the world's constructed facilities and the infrastructure on which modern civilization depends. These facilities can be large and complex and require that the engineer be broadly trained and able to deal with the latest technologies.

Civil and environmental engineers focus on the analysis, design, construction, maintenance, and operation of large-scale physical systems. To ensure the proper construction and care of these complex systems and environments, Rensselaer civil and environmental engineers develop a full range of skills in design, analysis, fabrication, communication, management, and teamwork. The current rebuilding of the world's roads, bridges, water and sewer systems, and other physical facilities has heightened society's awareness of the profession and given it added prominence. The growing panoply of sensors, instrumentation, intelligent facilities, and new materials is also highlighting the high-tech character of the discipline, creating new educational challenges and redefining the skill set that civil and environmental engineers need to succeed.

At Rensselaer, civil engineering has a long and distinguished history. In 1835, the Institute became the first U.S. school to issue a civil engineering degree. Among its graduates are William Gurley (1839) and Lewis E. Gurley (1845) partners in W&LE Gurley, Troy, N.Y., one of the first manufacturers of precision surveying instruments. Other world-renowned Rensselaer civil engineering graduates include:

- Francis Collingwood, Jr. (1855), honored by civil engineering's Collingwood Prize
- Washington Roebling (1857), builder of the Brooklyn Bridge
- Seijiro Hirai (1878), a president of the Imperial Railways, Japan
- George Ferris (1881), designer of the Ferris wheel
- Milton Brumer (1923), construction manager for the Verrazano Narrows Bridge
- Werner Ammann (1928), former partner, Ammann and Whitney
- Clay Bedford, Sr. (1925), general supervisor of the construction of the Bonneville and Grand Coulee Dams
- Ralph Peck (1934), co-author with Karl Terzaghi of the internationally-known book *Soil Mechanics in Engineering Practice*

Today, Rensselaer civil and environmental engineers continue to be found at all levels in both private and public sectors throughout the world.

A long-standing tradition at Rensselaer is educational programs in environmental problem solving. An early contribution to this field was the water analysis work of William Pitt Mason (1874), the pioneer of such activities in the U.S. in the late 1800s. Edward J. Kilcawley, a Rensselaer civil engineering professor who introduced environmental engineering as an option in the mid-1940s and as degree program in the mid-1950s, contributed visionary environmental engineering concepts.

In addition to those in the Department of Civil and Environmental Engineering, there are faculty members with teaching and research interests in environmental problem solving in the Departments of Chemical Engineering, Chemistry, Earth and Environmental Sciences, and Mathematical Sciences.

Research and Innovation Initiatives

Earthquake Engineering (Civil)

Rensselaer's earthquake engineering research program is concerned with seismic analysis and design methodologies that mitigate the negative impact of earthquakes on buildings, bridges, and pipelines (water, sewer, gas, and oil). It also focuses on analytical relationships that support decision-making and advance the state of the art in design codes, a key to future sustainability and durability. In these areas, Rensselaer's earthquake engineering research is among the best in the world. The Institute has a major geotechnical centrifuge facility and a 1 g shaking table for structural system testing. The geotechnical centrifuge facility, fourth largest in the U.S. and among the twenty largest in the world, has in-flight 2-D shaking and robotic capabilities. Both the centrifuge and the shaking table are the major experimental components of CEES (Center for Earthquake Engineering Simulation), a School of Engineering Interdisciplinary Research Center (see Center for Earthquake Engineering Simulation). CEES is one of the 15 experimental nodes of NEES (Network for Earthquake Engineering Simulation), an NSF Collaboratory initiative aimed at revolutionizing earthquake engineering research in the United States.

Structural Engineering (Civil)

Design and analysis of bridges, buildings, and other large-scale facilities; material selection and specification; structural technology selection; dynamic and static structural modeling and analysis; environmental loads on structures.

Geotechnical Engineering (Civil)

Behavior of soils and foundations under cyclic and dynamic loads; design methods to accommodate natural and man-made vibrations; geostochastics; soil dynamics, stability of earth slopes, structures, and dams.

Transportation Engineering (Civil)

This area of research includes design, analysis, maintenance, and operation of transportation systems and facilities; intelligent transportation systems, especially highway networks, goods distribution systems, and transit systems; real-time, multiobjective network management and control, including route guidance and dynamic traffic assignment; signal control systems; network management strategies; multiobjective routing and scheduling; and logistics decision making under uncertainty.

Computational Mechanics (Civil)

Studies involve the development of automated finite element modeling techniques, adaptive analysis procedures, development of adaptive multiscale solution techniques, qualification and modeling of engineering idealizations for analysis and design, design systems using knowledge-base techniques, prototype systems for applications including discrete crack propagation, forging simulations, multiple-scale modeling of composite materials and electronic packages, and unsteady aerodynamics.

Pollutant Fate and Transport (Environmental)

Research areas are assessment of pathogen loading and transport in water supplies and treatment systems, fate of hydrophobic organics in sediment, and environmental chemistry of PAHs.

Water Treatment (Environmental)

Researchers investigate the influence of natural organic matter properties and water chemistry on the formation of disinfection byproducts, understanding fouling mechanisms in the use of membrane processes in water treatment, membrane modifications for water treatment, adsorption processes and hybrid processes for removal of DBP precursors.

Waste Treatment (Environmental)

Studies focus on aerobic and anaerobic biological treatment reactors for municipal and industrial wastes; high strength anaerobic waste treatment in fluidized bed bioreactors with energy recovery, nutrient removal systems, hazardous waste treatment reactors, biofilters.

Site Remediation and Bioremediation (Environmental)

Research areas include combined advanced oxidation and biological treatment for sediment and soil slurry systems, in-situ degradation of chlorinated organics in groundwater, and solid phase treatment reactors for soils, slurries, and municipal solid wastes.

Environmental Systems (Environmental)

Under investigation are adaptive optimal control of treatment reactors, molecular modeling in environmental chemistry, and structure activity relationships.

Research Facilities

Rensselaer's centrifuge was commissioned in 1989 and began conducting physical model simulations of soil and soil structure systems subjected to in-flight earthquake shaking in 1991. In over a decade of successful operation, the facility has published results of some 500 earthquake-related model simulations, served as the basis for many M.S. and Ph.D. theses at Rensselaer, and contributed to Institute faculty and student research as well as that of dozens of visiting scholars and outside users from around the world. Recently the centrifuge facility was upgraded to a 150 g-ton overall capacity and enhanced with Web-based teleobservation and teleoperation wireless sensors, as part of its integration into NEES (Network for Earthquake Engineering Simulation), a national NSF-supported Collaboratory. Two modern telecontrol and teleconference rooms located close to the centrifuge facilitate collaboration and real-time experiments with the rest of NEES through a high-speed Internet connection. The geotechnical centrifuge is currently a main part of CEES (Center for Earthquake Engineering Simulation), a School of Engineering Interdisciplinary Research Center (see Center for Earthquake Engineering Simulation).

The Rensselaer 1 g seismic shaking table, located in the Jonsson Engineering Center High Bay Laboratory, is utilized to evaluate the behavior of scale-model structures subjected to dynamic loading. The shaking table, 1.6 m x 2.6 m in plan, is driven by a servo-controlled hydraulic actuator and is capable of reproducing a variety of input motions, including random motion for system identification testing and historical earthquake records for seismic testing. A variety of dynamic measurement sensors are available in the laboratory along with a spectrum analyzer and data acquisition system to process and record the measured signals.

A major upgrade in lab equipment and space for environmental engineering research and teaching has occurred through the establishment of the Keck Water Quality Laboratory, the National Science Foundation Environmental Colloid and Particle Laboratory, and the refurbishment of the Environmental Engineering Teaching Laboratory suite. Analytical equipment in these labs provides the capability for analysis and investigation of a wide variety of industrial processes, treatment processes, and polluted environments. This equipment gives students experience and expertise in treatability and toxicity studies, design and operation of bench-scale treatment systems, and investigation of a wide range of environmental quality parameters. The fate of specific compounds in the environment and in treatment processes can be analyzed by UV-VIS spectrophotometry, high pressure liquid chromatography, gas-liquid and gas chromatography with a number of specific and sensitive detectors, including electron capture, flame ionization, thermal conductivity, and mass spectral. Metals analyses by atomic absorption spectrophotometry and elemental analyses are also available. A complete suite of water quality monitoring equipment, field sampling systems, and geographical information system tools are available. Computational capabilities are widely accessible not only throughout the campus, but also in research laboratories, as well.

Faculty*

Professors

- Dobry, R.**—Sc.D. (Massachusetts Institute of Technology); geotechnical engineering, soil dynamics, earthquake engineering, seismic analysis.
- Dvorak, G.J.**—Ph.D. (Brown University); mechanics of solids, composite materials and structures, fracture and fatigue.
- Fish, J.**—Ph.D. (Northwestern University); computational mechanics, finite element methods, micromechanics, mathematical modeling.
- O'Rourke, M.J.**—PE., Ph.D. (Northwestern University); structures, lifeline earthquake engineering, snow loading on structures.
- Shephard, M.S.**—Ph.D. (Cornell University); computational mechanics, parallel processing, adaptive finite element techniques, automatic mesh generation.
- Wallace, W.A.**—Ph.D. (Rensselaer Polytechnic Institute); decision support systems, the process of modeling, environmental management, disaster management.
- Zimmie, T.F.**—PE., Ph.D. (University of Connecticut); geoenvironmental engineering, geotechnical engineering, groundwater hydrology, flow through porous media, landfills, centrifuge modeling, geosynthetics.

Associate Professors

- Abdoun, T.**—Ph.D. (Rensselaer Polytechnic Institute); geotechnical engineering, geotechnical centrifuge modeling, earthquake engineering.
- Holguín-Veras, J.**—PE. Ph.D. (The University of Texas at Austin); intelligent transportation networks, intermodal transportation, transportation planning and modeling, transportation economics.
- Kilduff, J.**—Ph.D. (University of Michigan); physicochemical processes, separations and recovery processes in water and wastewater treatment, effects of adsorption and mass-transfer on pollutant fate and transport in natural systems, membrane processes for water quality control.
- Nyman, M.C.**—Ph.D. (Purdue University); fate and transport of hydrophobic organic contaminants in natural systems, environmental chemistry.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting.

Symans, M.—Ph.D. (State University of New York at Buffalo); structural dynamics, earthquake engineering, seismic isolation and energy dissipation systems, structural vibration control.

Zeghal, M.—Ph.D. (Princeton University); soil dynamics and geotechnical earthquake engineering, computational geomechanics, geotechnical system identification and seismic response monitoring, damage diagnosis and nondestructive evaluation, and seismic risk analyses.

Assistant Professors

Cusatis, Gianluca—Ph.D. (Politecnico di Milano); computational and applied mechanics, heterogeneous materials, reinforced concrete structures, multi-hazard structural analysis.

Ukkusuri, Satish—Ph.D. (University of Texas, Austin); transportation network modeling, stochastic optimization, traffic operations, transportation safety and security.

Han, Jong-In—Ph.D. (University of Michigan); microbial molecular biology, bioremediation, bioavailability of hydrophobic contaminants, microbial communication (quorum sensing).

Montoya, Lupita—Ph.D. (Stanford University); indoor air quality, biological aerosols, health effects of aerosols, human exposure to air pollutants, environmental justice.

Clinical Associate Professor

Komisar, S.J.—Ph.D. (University of Washington); wastewater treatment, biological processes, solid waste management..

Adjunct Faculty (Civil Program)

Dall, J.—M.S. (Rensselaer Polytechnic Institute); structural engineering.

Floess, C.—Ph.D. (Rensselaer Polytechnic Institute); geotechnical engineering.

Kenneally, D.—B.S. (Rensselaer Polytechnic Institute); highway engineering.

O'Malley, D.—M.S. (Central Missouri State University); traffic engineering.

Griggs, F.—D.E. (Rensselaer Polytechnic Institute); structural engineering.

Reilly, J.—Ph.D. (Rensselaer Polytechnic Institute); transportation systems.

Westhuis, T.—B.S. (Rensselaer Polytechnic Institute); highway engineering.

Adjunct Faculty (Environmental Program)

Eslar, J.—PE., B.S. (Manhattan College) industrial waste treatment.

Hetling, L.—PE., Ph.D. (Rensselaer Polytechnic Institute) water resources.

Young, K.—J.D. (Harvard Law School) environmental law.

Emeritus Faculty

Clesceri, N.L.—Ph.D. (University of Wisconsin); advanced waste treatment, environmentally sound manufacturing, sediment decontamination.

Feeser, L.J.—PE., Ph.D. (Carnegie Mellon University); structures, computer applications and computer graphics, computer-aided design, structural optimization.

Undergraduate Programs

Civil Engineering Curriculum

Objectives of the Undergraduate Curriculum

While certain objectives of an undergraduate education in engineering are common to all programs, there are subtle but important differences depending upon the student's chosen field. In this regard, the Department of Civil and Environmental Engineering Department's baccalaureate program in Civil Engineering will:

- Prepare students to be involved, global citizens with a broad appreciation of the key civil engineering issues and challenges of the 21st Century.

- Provide students with the technical background needed for the practice of civil engineering and to ensure their competence and literacy in both problem identification and problem solving, including design.
- Prepare students for leadership in the profession, including civil engineering practice, societal activities, research, licensing, and ethics.
- Provide students with a broad educational base, including a foundation in math, science, and engineering and exposure to the humanities and social sciences that prepares them for life-long learning.
- Prepare students to thrive in the modern workplace and the public forums of civil engineering practice through the development of leadership, teamwork, and communication skills.

After completing the core engineering sequence, a student enters this curriculum and follows a baccalaureate program leading to the B.S. degree or a professional program leading to the M.Eng. degree as well as the B.S.

Undergraduate concentrations include construction, environmental, geotechnical, structural, and transportation engineering. Following the sample four-year schedule is the recommended collection of courses for each of these concentrations.

Subject to other requirements, students may use core engineering electives to accelerate their entrance into the program. Students also may take courses in related fields. Courses bearing the following codes are suggested for particular consideration in consultation with the student's adviser: ARCH, ECSE, MANE, ENVE, MATH, CSCI, EARTH, and DSES.

The following represents a typical four-year civil engineering program. Students who are convinced that they want to become civil engineers are urged to follow this plan of study in lieu of the general core engineering program presented earlier. Required or strongly recommended core engineering electives are shown for optimum scheduling.

First Year

Fall

	Credit hours
ENGR-1100 Intro. to Engineering Analysis.....	4
ENGR-1200 Eng. Graphics and CAD ¹	1
MATH-1010 Calculus I.....	4
CHEM-1100 Chemistry I.....	4
Hum. or Soc. Sci. Elective	4

Spring

	Credit hours
ENGR-1300 Engineering Processes ¹	1
PHYS-1100 Physics I.....	4
MATH-1020 Calculus II	4
Science Elective ²	4
Hum. or Soc. Sci. Elective	4

Second Year

Fall

	Credit hours
ENGR-2050 Intro. to Engineering Design	4
MATH-2400 Intro. to Differential Equations	4
PHYS-1200 Physics II.....	4
Hum. or Soc. Sci. Elective	4

Spring

	Credit hours
ENGR-2090 Engineering Dynamics	4
ENGR-2530 Strength of Materials	4
Multidisciplinary Elective I ³	4
Hum. or Soc. Sci. Elective	4
CSCI-1190 Beginning C Programming for Engineers ⁴	1

¹ For these two courses, order does not matter. ENGR-1300 may be replaced with CIVL-2961.

² Choose either ENGR-1600 or CSCI-1100.

³ For Multidisciplinary Elective I, choose either ENGR-2250 or ENGR-4750. For Multidisciplinary Elective II, choose either ENGR-2350 or ENGR-4300.

⁴ Can be satisfied with Computer Science I.

Third Year**Fall**

CIVL-2030	Intro. to Transportation Eng.....4
CIVL-2630	Intro. to Geotechnical Eng.....4
CIVL-2670	Intro. to Structural Eng.....4
ENGR-2600	Modeling and Analysis of Uncertainty.....3

Credit hours**Spring****Credit hours**

Multidisciplinary Elective II ³4
CE Design Elective ⁵3
Professional Development II ⁶2
Math and Science Elective.....3-4
Free Elective.....4

Fourth Year**Fall**

ENVE-2110	Intro. to Environ. Eng.....4
CIVL-4120	CE Instrumentation and Sensors.....4
	CE Design Elective ⁵3
	Free Elective.....4

Credit hours**Spring****Credit hours**

CIVL-4920	Civil Eng. Capstone Design.....3
ENGR-4010	Professional Development III ⁷1
	CE Technical Elective ⁵3
	Hum. or Soc. Sci. Elective.....4
	Free Elective.....4

A minimum of 128 credit hours is required for this curriculum. Nonengineering courses graded satisfactory/unsatisfactory are not included within this 128-credit-hour requirement. The Pass/No Credit option can be used only for free electives with something other than a CIVL or ENVE code and the humanities and social sciences electives. All other courses used to satisfy the degree requirements must be taken on a graded basis.

Civil Engineering Design Electives and Concentrations

Six credit hours of civil engineering design electives are required. These must be selected from the following list. Any pair of courses can be selected providing that prerequisites are met, but students most often select a combination focused on a specific area of concentration. The terms in which courses are offered are listed in parentheses.

Construction Engineering

CIVL-4070	Steel Design (Fall)
CIVL-4080	Concrete Design (Spring)
CIVL-4010	Foundation Engineering (Fall)
CIVL-4150	Experimental Soil Mechanics (Spring)

Structural Engineering

CIVL-4070	Steel Design (Fall)
CIVL-4080	Concrete Design (Spring)
CIVL-4960	Bridge Design (Spring)*

Environmental Engineering

ENVE-4200	Solid and Hazardous Waste Engineering (Spring)
ENVE-4350	Biological Processes in Environmental Engineering (Fall)

ENVE-4310	Applied Hydrology and Hydraulics (Spring)
ENVE-4340	Physicochemical Processes in Environmental Engineering (Spring)

Geotechnical Engineering

CIVL-4010	Foundation Engineering (Fall)
CIVL-4140	Geoenvironmental Engineering (Fall)
CIVL-4150	Experimental Soil Mechanics (Spring)

Transportation Engineering

CIVL-4620	Mass Transit Systems (Spring)
CIVL-4640	Transportation Facility Design and Planning (Spring)
CIVL-4660	Traffic Engineering (Fall)
CIVL-4670	Highway Engineering (Spring)

³ For Multidisciplinary Elective I, choose either ENGR-2250 or ENGR-4750. For Multidisciplinary Elective II, choose either ENGR-2350 or ENGR-4300.

⁵ Text below lists the allowable courses.

⁶ Choose either PSYC-4170 or STSS-4840.

⁷ Can be taken either semester of the senior year.

* Special topics course.

Civil Engineering Technical Elective

Any of the design electives listed above can be taken as a CE technical elective, provided the necessary prerequisites are met. The following other civil engineering courses can also be selected:

CIVL-2040	Professional Practice	CIVL-4270	Construction Management
CIVL-2130	Surveying	CIVL-4440	Structural Analysis
CIVL-4240	Intro. to Finite Elements	CIVL-4580	Infrastructure Engineering

With adviser approval, courses from related disciplines can also be taken. These include architecture, environmental engineering, earth and environmental sciences, mechanical engineering, chemical engineering, industrial engineering, and operations research. Graduate level courses (6000-level) are allowable under certain circumstances. A representative list of such courses is as follows:

ARCH-4510	Construction Industry Seminar	ENVE-4200	Solid and Hazardous Waste Engineering
ARCH-4530	Systems Building Seminar	ENVE-4310	Applied Hydrology and Hydraulics
ARCH-4550	Building Economics	MATH-4800	Numerical Computing
ARCH-4750	Advanced Environmental Systems	ERTH-2120	Structural Geology
ENGR-4750	Engineering Economics and Project Management	ERTH-2330	Earth Materials
ENVE-4110	Aqueous Geochemistry	ERTH-4200	Surficial Geology
		ERTH-4710	Ground Water Hydrology

Humanities or Social Sciences Electives

In this area, the electives are based on the Institute and School of Engineering requirements. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Environmental Engineering Curriculum

Objectives of the Undergraduate Curriculum

While certain objectives of an undergraduate education in engineering are common to all programs, there are subtle but important differences depending upon the student's chosen field. In this regard, the Civil and Environmental Engineering Department's baccalaureate program in Environmental Engineering will:

- Prepare students to be involved global citizens with a broad appreciation of the key environmental issues and challenges of the 21st Century.
- Provide students with a broad educational base, including a foundation in math, science, and engineering and exposure to the humanities and social sciences that will prepare them for life-long learning.
- Provide students with the technical background needed for the practice of environmental engineering and to insure their competence and literacy in both problem identification and solving, including design.
- Prepare students for professional engineering practice, including professional licensing, with awareness of the importance of personal and professional ethics.
- Prepare students to thrive in the modern workplace and the public forums of environmental engineering practice through the development of leadership, teamwork, and communication skills.

The Rensselaer bachelor's program in environmental engineering builds upon a broad base of studies in chemistry, life sciences, and engineering sciences culminating in a uniquely structured course sequence. This sequence of courses, as shown below, is designed around the unit operations and transport processes concepts, together with integrated laboratory theory courses. It culminates in senior design courses. This structure presents a unified educational experience in environmental engineering. A minimum of 128 credit hours is required for this curriculum.

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis	4	PHYS-1100	Physics I	4
MATH-1010	Calculus I.....	4	MATH-1020	Calculus II	4
CHEM-1100	Chemistry I.....	4	ENGR-1600	Material Science for Engineers.....	4
ENGR-1200	Engineering Graphics and CAD ¹	1	ENGR-1300	Engineering Processes or	
	Hum. or Soc. Sci. Elective	4	ENGR-1310	Intro. to Eng. Electronics ¹	1
				Hum. or Soc. Sci. Elective	4

Second Year

Fall		Credit hours	Spring		Credit hours
PHYS-1200	Physics II	4	ENGR-2600	Modeling and Analysis of	
MATH-2400	Intro. to Differential Equations	4		Uncertainty	3
ENVE-2110	Intro. Environmental Eng.	4	ENGR-2050	Intro. to Engineering Design ²	4
CHEM-2250	Intro. to Organic Chemistry	3		Hum. or Soc. Sci. Elective	4
				Free Elective I	4
			CSCI-1190	Beginning C Programming for	
				Engineers	1

Third Year

Fall		Credit hours	Spring		Credit hours
CHME-4010	Fluid Mech. and Heat Transfer ³	4	ENVE-4310	Applied Hydrology and Hydraulics ..	3
ENVE-4330	Atmospheric Pollution	3		Technical Elective I ⁴	3
	Free Elective II	4	ENVE-4320	Environmental Chemodynamics	3
	Hum. or Soc. Sci. Elective	4	ENVE-4340	Physicochem. Proc. in Env. Eng.	3
	Professional Development II ¹	2	CHME-4030	Chem. Process Dyn. and Control	4

Fourth Year

Fall		Credit hours	Spring		Credit hours
ENVE-4350	Biol. Proc. in Env. Eng.	4	ERTH-4180	Environmental Geology.....	4
ENVE-4150	Environmental Eng. Lab	4		Technical Elective II ⁴	3
	Multidisciplinary Eng. Elec. I ⁵	4	ENVE-4180	Env. Proc. Design	3
	Hum. or Soc. Sci. Elective	4		Free Elective III	4
ENGR-4010	Professional Development III ⁶	1			

¹ May be taken in any order in the first two semesters. ENGR-1300 or ENGR-1310 may be replaced with CIVL-2961.

² Special section for environmental engineering students.

³ May be replaced by ENGR-2250.

⁴ Elective must be an engineering course with design content (e.g., ENVE-4200, ENVE-4240, ENVE-4210, ENVE-4110). Courses are selected in consultation with the program adviser. With adviser approval, courses from other disciplines may also be taken. These include Civil Engineering, Chemical Engineering, Earth and Environmental Sciences (for example, CIVL-2630, CIVL-4150, EARTH-4710 and others).

⁵ Multidisciplinary engineering, elective: Must be an engineering course, chosen in consultation with the adviser (e.g., ENGR-4750, ENGR-4760, CIVL-2030, CIVL-2630, DSES-4260, ENGR-2530, ENGR-2830).

⁶ This course will be fulfilled from a published list at the start of each semester and can be taken either semester.

Minor Programs

The department offers minors in both civil and environmental engineering.

Civil Engineering

Students not majoring in civil engineering may receive a minor in this field by completing 5 courses selected from the following list (subject to consultation with a civil engineering department program adviser):

CIVL-2030	Intro. to Transportation Engineering	CIVL-4080	Concrete Design
CIVL-2630	Intro. to Geotechnical Engineering	CIVL-4150	Experimental Soil Mechanics
CIVL-2670	Intro. to Structural Engineering	CIVL-4400	Advanced Structural Analysis
ENVE-2110	Intro. to Environmental Engineering	CIVL-4660	Traffic Engineering
CIVL-4010	Foundation Engineering	CIVL-4670	Highway Engineering
CIVL-4070	Steel Design		

Students pursuing this minor must satisfy the prerequisites and/or corequisites for these courses, which may involve other course work.

Recommended Courses for Students in Bachelor of Architecture Program

Given the close link between architecture and civil engineering, the following set of courses are recommended for students in the Bachelor of Architecture program who are interested in completing a minor in civil engineering with an emphasis in structural engineering.

Take all of the following:

CIVL-2670	Intro. to Structural Engineering (4 cr.)
CIVL-4070	Steel Design (3 cr.)
CIVL-4080	Concrete Design (3 cr.)

Take two additional courses from the following:

CIVL-2630	Intro. to Geotechnical Engineering (4 cr.)
CIVL-4010	Foundation Engineering (3 cr.)
CIVL-4150	Experimental Soil Mechanics (3 cr.)
CIVL-4270	Construction Management (3 cr.)
CIVL-4440	Structural Analysis (3 cr.)

Notes:

- 1) Completion of MATH-1010 is recommended prior to enrolling in Civil Engineering courses. However, MATH-1500 is an acceptable alternative to MATH-1010.
- 2) The core engineering courses ENGR-1100 & 2530 are prerequisites for many of the civil engineering courses. These core courses are waived for students who have completed ARCH-2330 with a grade of B or higher.
- 3) Subject to approval of the School of Architecture program adviser, ARCH-4330 will be waived for students who complete CIVL-2670, 4070, and 4080. Since ARCH-4330 is part of the Bachelor of Architecture core program, students will be required to substitute a 4-credit elective in its place.
- 4) Bachelor of Architecture students pursuing this minor should recognize that some of the civil engineering courses may rely on material from some of the core engineering courses (i.e., ENGR-1100, ENGR-2090, MATH-1010, MATH-1020, MATH-2400, and PHYS-1100). Thus, the student should anticipate the possible need for some self-study while taking the civil engineering courses.

Environmental Engineering

Students not majoring in environmental engineering may receive a minor in this discipline by completing 15–16 credit hours of study beyond the Introduction to Environmental Engineering course. Typically these courses are chosen in consultation with the environmental engineering program adviser but may include:

ENVE-4260	Biological Processes in Environmental Engineering	<i>And one or more of:</i>	ENVE-4200	Solid and Hazardous Waste
ENVE-4340	Physicochemical Process in Environmental Engineering		ENVE-4330	Atmospheric Pollution
ENVE-4310	Applied Hydrology and Hydraulics		ENVE-4320	Environmental Chemodynamics

Professional Program

This program is intended primarily as a preparation for professional practice. After core engineering study, qualified undergraduates may enter this program, which leads to the B.S. and the M.Eng. degrees. Students follow a coherent program integrating advanced undergraduate and graduate study. An additional 30 credit hours are required beyond the B.S. degree.

Graduate Programs

Graduate programs leading to the M.Eng., M.S., D.Eng., and Ph.D. are available in both curricula. The selection of a graduate program and degree is based on student interest, area of graduate concentration, and satisfaction of prerequisites as indicated below.

Master's Programs

Master of Science

This research degree is open to students with undergraduate degrees in engineering or the physical or natural sciences. In addition to the satisfactory completion of an approved set of advanced courses, candidates for this degree must complete a six-credit thesis.

In the civil engineering discipline, this thesis must provide documentation of an independent research-related effort and be approved by the student's faculty adviser. Listed below are recommended core courses in each of the five civil engineering areas of concentration and in Environmental Engineering. M.S. candidates typically take all the courses listed below in their chosen area of concentration.

Computational Mechanics

CIVL-6170	Mechanics of Solids
CIVL-6660	Fundamentals of Finite Elements
CIVL-6670	Nonlinear Finite Element Methods
CIVL-6680	Finite Element Programming

Geotechnical/Earthquake Engineering

CIVL-6510	Advanced Soil Mechanics
CIVL-6520	Advanced Foundations of Earth Structures
CIVL-6550	Advanced Geoenvironmental Engineering

CIVL-6450	Structural Dynamics
CIVL-6540	Dynamics of Soil and Soil Foundations Systems

Structural/Earthquake Engineering

CIVL-4240	Introduction to Finite Elements
CIVL-6200	Plates and Shells
CIVL-6210	Structural Stability
CIVL-6310	Advanced Concrete Structures
CIVL-6320	Advanced Steel Design
CIVL-6450	Structural Dynamics
CIVL-6540	Dynamics of Soil and Soil Foundation Systems

M.S. candidates in the environmental engineering discipline must also provide documentation of an independent research-related effort. In addition to approval of this written work, they are also required to give an oral presentation of the thesis work.

Master of Engineering

This is a 30-credit structured program of advanced professional study aimed at preparing students for professional practice. Except for computational mechanics, candidates for this degree in the civil engineering discipline must have an accredited bachelor's degree in engineering. In environmental engineering, a B.S.

in the physical or natural sciences is also acceptable. There is no project or thesis requirement, but students may elect to do one, at either the three- or six-credit level, in consultation with their advisers.

Doctoral Programs

Advanced study and research are conducted under the guidance of an adviser. Usually 45 to 60 course credits beyond the bachelor's degree are required in addition to the residence and thesis requirements. Each doctoral candidate must have at least 90 credits (course work plus thesis/project) beyond the bachelor's degree. Environmental candidates are required to submit a draft of a journal article prior to graduation.

Doctor of Philosophy

This is a research-oriented degree focused on the development of new knowledge in the student's chosen area of study. It includes the preparation of a dissertation that carefully documents the original contribution of the student's research. The dissertation can represent up to 30 credits of the student's approved Plan of Study. In addition to the examination processes required of all Rensselaer doctoral students, civil engineering and environmental engineering students working toward this degree must pass a qualifying examination during student's second semester if student has a M.S. degree counting as a degree requirement or at the end of the student's fourth semester if student does not have a M.S. degree counting as a degree requirement.

Environmental engineering students must also take a candidacy examination within two semesters after passing the preliminary examination. This is an oral examination based on a thesis proposal submitted by the student at least two weeks prior to the examination. The student's thesis committee will administer the candidacy examination.

Doctor of Engineering

This is a specialized program aimed at advanced engineering problem solving. The degree includes the preparation of a dissertation that poses a significant engineering problem and develops a solution. The dissertation for this degree can also represent up to 30 credits of the student's approved Plan of Study. The examination requirements for both disciplines are the same as those noted under the Doctor of Philosophy.

Course Descriptions

Courses directly related to all Civil and Environmental Engineering curricula are described in the Course Description section of this catalog under the department codes CIVL and ENVE.

Decision Sciences and Engineering Systems

Department Head: James M. Tien

Associate Head and Director, Master's Programs: Charles J. Malmborg

Director, Doctoral Program: Thomas Willemain

Director, Undergraduate Program: Charles J. Malmborg

Department Home Page: <http://www.dses.rpi.edu>

The formation of the Decision Sciences and Engineering Department in 1987 is a prime example of Rensselaer's ability to anticipate the changing needs of the engineering profession. The department was created to (1) prepare engineers to design, develop, and implement complex systems and (2) to conduct research that leads to better understanding of how information technology and quantitative analysis and modeling can support individuals, groups, and systems in problem solving and decision making. DSES

achieves these objectives by extending and integrating knowledge from the disciplines of industrial engineering, information systems, operations research, mathematical statistics, computational intelligence, bioinformatics, and systems engineering.

The Department of Decision Sciences and Engineering Systems offers programs in industrial and management engineering, service and manufacturing systems engineering, and operations research and statistics. Curricula in management engineering and/or industrial engineering have been offered since 1933. The interdisciplinary graduate program in operations research and statistics (OR&S) at Rensselaer was established in response to the rapid increase in the use of mathematical models for characterizing systems, understanding operations, and making decisions. Both a master's and a doctoral program were initiated in 1967. However, in 1988, the department replaced the OR&S Ph.D. with a unique Ph.D. degree in Decision Sciences and Engineering Systems, reflecting the focus of the new department. The program in Manufacturing Systems Engineering was inaugurated in the fall of 1992, and has been updated to the current degree program in Service and Manufacturing Systems Engineering. This program is designed to emphasize modeling, statistical, computer, and management skills as they relate to service operations and the process of manufacturing. A common theme throughout these programs is the use of mathematical, statistical, and computational/simulation models to better understand engineering, managerial, operational, and physical processes.

Research and Innovation Initiatives

Manufacturing Systems

Faculty have developed methodologies and procedures for infrastructure and operating systems (e.g., production planning and control, scheduling, and dispatching in flexible manufacturing systems), simulation of production facilities, manufacturing logistics, materials handling engineering, manufacturing facility design, information integration for design and manufacturing, control systems and agile manufacturing concepts for the electronics industry, and methodologies to integrate statistical quality control with computer graphics.

Service Systems

This area concentrates on the application of traditional and evolving industrial and systems engineering methodologies to the design and operation of service systems in both industry and the public sector. Areas of interest include simulation modeling and analysis, distribution and logistics, facilities design, work design, quality assurance, intelligent transportation systems, and engineering economic analysis. Also included is research in the deployment, allocation, and operation of urban service systems using computationally-intensive, real-time decision support approaches.

Information Systems

Information and decision support systems have been developed and extensively used for disaster preparedness and management of disasters (e.g., searches for ships lost at sea, earthquakes) and manufacturing enterprises (e.g., manufacturing-driven design and scalable adaptive integration of databases over wide area networks). New theory and methodologies for Internet-based information integration, e-commerce, data mining, and knowledge discovery are being developed. Decision support systems are being developed using a variety of knowledge engineering and computational intelligence tools. Also under development are methods, models, and technologies to aid in the planning and design of distributed information systems, information visualization, and user interfaces.

Mathematical Programming

Research topics include linear, nonlinear, integer, large-scale, multiple-objective, combinatorial,

geometric, and stochastic programming. Of particular interest is research on the development and analysis of algorithms, computation, and the integration of uncertainty in optimization.

Statistics and Applied Probability

Research is conducted in the areas of real-time data fusion and analysis, data mining, knowledge discovery, and design of experiments—including optimality, efficiency, and robustness; nonlinear and robust estimation; statistical computing; probability; stochastic processes; queuing theory; reliability; quality control; and forecasting.

Facilitating these research programs are three research centers based directly within the Decision Sciences and Engineering Systems Department. Every department faculty member is involved in one or more of these research centers. In addition, several other faculty in the School of the Engineering, as well as in the other four schools, are also participating in activities conducted in the centers described below:

Electronics Agile Manufacturing Research Institute (EAMRI)

<http://www.eamri.rpi.edu>

The EAMRI grew out of a federally funded, five-year project focused on agile manufacturing information technologies as a strategy to help the electronics manufacturing industry achieve its goals. Agile manufacturing concepts employ network-based information for supply chain-oriented technologies and organizations, as well as improved communications to help solve design and manufacturing problems. The EAMRI provides a national focus for developing and sharing methods to enable the U.S. electronics industry to adopt agile manufacturing. Experts in electronics design and manufacturing, the EAMRI faculty possess engineering, computer science, and management backgrounds. The EAMRI's initial information technology, known as the Virtual Design Environment, has recently received a patent from the U.S. Patent Office.

Center for Services Research and Education (CSRE)

<http://www.dses.rpi.edu/research/csre.cfm>

The goal of the CSRE is to enhance our understanding of the service sector and its function, and to educate students and managers seeking careers in the services industry, which accounts for more than three-quarters of the U.S. gross national product. CSRE faculty were one of the first groups to highlight the duality between services and manufacturing; many manufacturing methods are applicable to service systems and can be employed to enhance productivity and competitiveness. The CSRE takes a holistic approach to the multifaceted service sector and brings together experts from engineering, marketing, psychology, economics, and management policy and organization, among others. Experts examine the common elements that characterize all aspects of the service sector and develop generic principles that apply across the wide spectrum of services, including the advancement of a focus in service systems engineering.

Rensselaer Statistical Consulting Center (RSCC)

<http://www.dses.rpi.edu/research/rscc.cfm>

The RSCC provides statistical planning and analysis services to Rensselaer researchers who require them. It also consults with companies and government agencies that require advice on state-of-the-art statistical and probabilistic methods and their applications. In addition, it allows graduate students to apply, in a supervised manner, established and new statistical and probabilistic approaches to real-world problems, and offers general and organization-specific short-term training programs and state-of-the-art courses in statistical methodologies and practices. The Center's faculty represent a range of statistical expertise, and they have extensive research and consulting experience. These faculty members, together with talented graduate students, provide advice and guidance on the appropriate use of statistical and probabilistic methods, on a consulting or short course basis.

Faculty*

Professors

- Berg, D.**—NAE, Ph.D. (Yale University) Institute Professor of Science and Technology (joint in Lally School of Management and Information Technology); management of technological organizations, innovation, policy, robotics, policy issues of research and development in the service sector.
- Ecker, J.G.**—(Mathematical Sciences) Ph.D. (University of Michigan); mathematical programming, multiobjective programming, geometric programming, mathematical programming applications, ellipsoid algorithms.
- Hsu, C.**—Ph.D. (Ohio State University); electronic commerce, metadata and information systems, enterprise integration and modeling, internet enterprises planning, computerized manufacturing, information visualization, economic evaluation of cyberspace-augmented enterprises.
- Hughes, G.**—(Economics) Ph.D. (Princeton University); global economics, economics of information technology; Clinical Professor.
- Malmborg, C.J.**—Ph.D. (Georgia Institute of Technology); modeling and analysis of problems in facility design, materials handling, material flow, storage systems, simulation-based optimization methods, manufacturing systems, decision analysis.
- Mitchell, J.E.**—(Mathematical Sciences) Ph.D. (Cornell University); mathematical programming integer programming, interior point methods, column generation methods, financial optimization, stochastic programming.
- Pang, J.S.**—(Mathematical Sciences) Ph.D. (Stanford University); Mathematics of Finance and Mathematical Statistics.
- Tien, J.M.**—NAE, Ph.D. (Massachusetts Institute of Technology) Yamada Corporation Professor (joint in Electrical, Computer, and Systems Engineering; IT); systems modeling, queuing theory, public policy and decision analysis, computer performance evaluation, and information and decision support systems, expert systems, computational cybernetics.
- Wallace, W.A.**—Ph.D. (Rensselaer Polytechnic Institute) (joint in Civil Engineering; Cognitive Sciences; IT); decision support systems, environmental management modeling process, disaster management.
- Willemain, T.R.**—Ph.D. (Massachusetts Institute of Technology); probabilistic modeling, data analysis, forecasting.

Associate Professors

- Embrechts, M.J.**—Ph.D. (Virginia Polytechnic Institute); application of neural networks and fuzzy logic for manufacturing and process control; image recognition and classification with the aid of neural networks; smart experiments; neural networks for trading and finance; neural networks, fractals, chaos, and wavelets for time-series analysis; data mining and computational intelligence.
- Foley, W.J.**—P.E., Ph.D. (Rensselaer Polytechnic Institute); engineering design, computer simulation modeling, health applications of operations research, health case policy analysis; Clinical Associate Professor.
- Holguin-Veras, J.**—(Civil and Environmental); Ph.D. (University of Texas/Austin); transportation modeling and transportation economics, information technology, information systems, optimization techniques.

Assistant Professors

- Aboul-Seoud, M.**—Ph.D. (University of Louisville); reliability engineering, quality control, operations research; Clinical Assistant Professor.
- Carbone, M.J.**—Ph.D. (Rensselaer Polytechnic Institute); modeling, manufacturing and service operations, queuing theory, Clinical Assistant Professor.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting.

- Chan, W.K.** —Ph.D. (University of California at Berkeley); discrete event simulation, design and analysis of manufacturing and service systems, mathematical statistics, queuing theory.
- Gupta, A.** —Ph.D. (Stanford University); behavioral aspects of optimization and application problems in finance, large-scale problems in decision making, simulation methods and tools for solving large-scale problems, simulation-based optimization.
- Krishnamurthy, A.** —Ph.D. (University of Wisconsin-Madison); queuing models and simulation based approaches for design and analysis of manufacturing systems, quick response manufacturing, queuing networks, analytical models in fabrication/assembly systems.

Adjunct Faculty

- Bonnison, P.** —Ph.D. (University of California at Berkeley); approximate reasoning, soft computing, fuzzy logic, intelligent control.
- Hahn, G.** —Ph.D. (Rensselaer Polytechnic Institute); applied statistics, operations research.
- Heragu, S.S.** —Ph.D. (University of Manitoba); artificial intelligence, cellular manufacturing, facilities design, intelligent manufacturing systems, materials handling, next-generation factory layout design, production and operations management, operations research, scheduling, storage and warehousing.
- Kupferschmid, M.** —P.E., Ph.D. (Rensselaer Polytechnic Institute); mathematical programming, algorithm performance evaluation, engineering applications.
- Osborn, B.E.** —Ph.D. (Brown University);
- Pavarini, C.** —Ph.D. (Rensselaer Polytechnic Institute); Internet infrastructure, optical components, applications software markets.
- Stephens, P.** —M.S. (Rensselaer Polytechnic Institute); Statistics and Operations Research.
- Whitehouse, J.M.** —M.S. (Harvard University); industrial safety and hygiene.
- Zurbenko, I.G.** —Ph.D. (Moscow State University); Biometry and Statistics.

Affiliated Professors

- Bennett, K.** —(Mathematical Sciences) Ph.D. (University of Wisconsin); mathematical programming, operations research, artificial intelligence.
- Bringsjord S.** —(Cognitive Sciences) Ph.D. (Brown University); logic and artificial intelligence, foundations of artificial intelligence and cognitive science, computation creativity.
- Desrochers, A.** —(Electrical, Computer, and Systems Engineering) Ph.D. (Purdue University); performance modeling of automated manufacturing systems application to Petri nets, transfer lines, manufacturing architectures, database and network transactions, distributed systems.
- Kelly, L.J.** —(Rensselaer at Hartford) Ph.D. (University of Connecticut); statistics, operations management.
- Maleyeff, J.** —(Rensselaer at Hartford) Ph.D. (University of Massachusetts); statistical quality assurance in manufacturing, administration and health care; computer simulation of operating systems; development of effective teaching methodologies.
- Paulson, A.S.** —(Lally School of Management and Technology) Ph.D. (Virginia Polytechnic Institute); risk management, financial models, multivariate statistics, time series and forecasting, survival data analysis.

Affiliated Associate Professors

- Arnheiter, E.D.** —(Rensselaer at Hartford) Ph.D. (University of Massachusetts); Monte Carlo simulation and probabilistic models in quality, modular consortiums, and automotive production models.
- Franklin, W.R.** —(Electrical, Computer, and Systems Engineering) Ph.D. (Harvard University); computational geometry, graphics, CAD, cartography, parallel algorithms, large databases, expert system verification.
- Goldenberg, D.H.** —(Lally School of Management and Technology) Ph.D. (University of Florida); derivatives markets, stochastic modeling of prices, options in corporate finance.

Gutierrez-Miravete, E.—(Rensselaer at Hartford) Ph.D. (Massachusetts Institute of Technology); materials processing, transport phenomena, clean technologies, advanced mathematics for applications, numerical computing, mathematical modeling, computer simulation.

Ravichandran, T.—(Lally School of Management and Technology) Ph.D. (Southern Illinois University, Carbondale); management information systems.

Zaki, M.J.—(Computer Sciences) Ph.D. (University of Rochester); design of efficient, scalable, and parallel algorithms for various data mining techniques.

Affiliated Assistant Professor

Martin, L.L.—(Chemical and Biological Engineering) Ph.D. (University of California at Los Angeles); process systems engineering, design for waste minimization and pollution prevention.

Yang, Y.—(Cognitive Science) Ph.D. (New York University); cognitive psychology, thinking, reasoning, decision-making, cognitive science.

Research Professors

Grabowski, M.—Ph.D. (Rensselaer Polytechnic Institute); management information systems, knowledge-based systems, human and organizational error in large-scale systems, impact of information technology on systems and organizations.

Graves, R.J.—Ph.D. (State University of New York at Buffalo); manufacturing systems modeling and analysis, facilities planning and material handling system design, scheduling systems, concurrent engineering and design for manufacture, continuous flow manufacturing systems design, distributed manufacturing concepts, information infrastructure.

Emeritus Faculty

Graves, R.J.—Ph.D. (State University of New York at Buffalo); manufacturing systems modeling and analysis, facilities planning and material handling system design, scheduling systems, concurrent engineering and design for manufacture, continuous flow manufacturing systems design, distributed manufacturing concepts, information infrastructure.

Raghavachari, M.—Ph.D. (University of California at Berkeley); statistical inference, quality control, multivariate methods, scheduling problems.

Sullo, P.—Ph.D. (Florida State University); reliability, life testing, statistical quality control, management, biostatistics, industrial statistics.

Wilkinson, J.—Ph.D. (University of North Carolina); regression modeling, statistical analysis.

Undergraduate Programs

<http://www.dses.rpi.edu/programs/undergrad.cfm>

Objectives of the Undergraduate Curriculum

While certain objectives of an undergraduate education in engineering are common to all programs, there are subtle but important differences ensuring that all graduates have specialized technical knowledge in their chosen field. In this regard, the Department of Decision Sciences and Engineering Systems baccalaureate program educates students in the fundamental theories, principles, methodologies, and practices of Industrial and Management Engineering while seeking to develop in its graduates:

- The ability to apply a total integrated systems perspective to the practice of industrial and management engineering.
- The ability to apply knowledge of manufacturing and service systems to the practice of industrial and management engineering.

- The ability to apply in-depth knowledge of computing to the practice of industrial and management engineering.
- The ability to manage people and systems.
- The ability to design innovative products, services, facilities, equipment, processes, and systems.
- The ability to identify, model, analyze, and solve challenging real-life problems.
- A solid foundation in math and science.
- Strong communication skills with emphasis on technical writing and interpersonal communication.
- The ability to perform effectively on diverse teams, both as leader and contributor.
- Informed citizens broadly educated in the humanities and social sciences.
- Preparation to practice engineering in a socially responsible and ethical manner.
- Motivation and preparation for continued growth and learning.

Baccalaureate Programs

The Department of Decision Sciences and Engineering offers a curriculum in Industrial and Management Engineering (IME). The first two years of this curriculum provide a strong foundation in basic science, engineering science, mathematics, and the humanities and social sciences. These two years are oriented toward the quantitative (mathematical) approach. Computer-based technology, including simulation, modeling, and systems design, is emphasized. In the last two years of the program, students concentrate on building expertise in statistics, operations research, manufacturing, and services systems engineering, and industrial engineering methods and models. Through the appropriate choice of electives, students can focus on their selected areas of interest. Design projects include problems in both manufacturing and service systems, including information and public systems. It is advisable to develop a Plan of Study leading to the desired degree and concentration by the beginning of the third year.

DSES recommends that students declare their intent to major in industrial and management engineering as early as possible in their academic career. Students are also urged to work closely with their assigned faculty advisers to ensure that all degree requirements are satisfied. This curriculum requires a minimum of 128 credit hours and completion of the course requirements shown in the typical four-year program presented below.

Industrial and Management Engineering Undergraduate Degree

First Year

Fall	Credit hours	Spring	Credit hours
ENGR-1100	Introduction to Engineering	ENGR-1200	Engineering Graphics & CAD1
	Analysis4	MATH-1020	Calculus II4
ENGR-1300	Engineering Processes1	PHYS-1100	Physics I4
MATH-1010	Calculus I4		Science Elective ¹4
CHEM-1100	Chemistry I4		Hum. or Soc. Sci. Elective4
	Hum. or Soc. Sci. Elective4		

¹ Students are encouraged to select a life science course such as BIOL-1010.

Second Year**Fall**

	Credit hours	
ENGR-2050 Introduction to Engineering Design	4	
MATH-2400 Intro. to Differential Equations	4	
PHYS-1200 Physics II	4	
	Hum. or Soc. Sci. Elective	4

Spring

	Credit hours	
ENGR-2600 Modeling and Analysis of Uncertainty	3	
CSCI-1190 C Programming	1	
DSES-2210 Prod. & Ops. Mgt. & Cost. Acctg.	4	
	Multidisciplinary Engineering Elective ²	3-4
	Management Elective ³	4

Third Year**Fall**

	Credit hours	
DSES-4140 Statistical Analysis	4	
DSES-4610 Operations Research I	3	
	Multidisciplinary Engineering Elective ²	3-4
	Hum. or Soc. Sci. Elective	4
	Professional Development II ⁴	2

Spring

	Credit hours	
DSES-4620 Operations Research II	3	
DSES-4230 Quality Control	3	
ENGR-4760 Eng. Economics	3	
	Hum. or Soc. Sci. Elective	4
	Free Elective	4

Fourth Year**Fall**

	Credit hours	
DSES-4530 Information Systems	4	
DSES-4962 Discrete Event Simulation	3	
	Technical Elective ⁵	3
	Free Elective	4

Spring

	Credit hours	
DSES-4270 IME Design ⁶	3	
ENGR-4100 Professional Development III ⁶	1	
DSES-4961 Supply Chain Management	3	
	Technical Elective ⁵	3
	Free Elective	4

² Students must select any two of the following approved multidisciplinary electives:

ENGR-1600 Materials Science for Engineers	ENGR-2710 General Manufacturing Processes
ENGR-2090 Engineering Dynamics	ENGR-4050 Mod. & Control of Dynamic Systems
ENGR-2250 Thermal and Fluid Engineering I	ENGR-4300 Electronic Instrumentation
ENGR-2350 Embedded Control	ENGR-4710 Adv. Mfg. Lab I
ENGR-2530 Strength of Materials	ENGR-4720 Adv. Mfg. Lab II

³ Students may select any one of the following courses to satisfy the management elective requirement:

ECON-2010 Manag. Economics	MGMT-4510 Invention, Innovation & Entrepreneurship
ECON-4210 Cost Benefit Analysis	MGMT-4520 Technological Entrepreneurship
MGMT-1100 Introduction to Management	MGMT-4530 Starting Up a New Venture
MGMT-2320 Accounting for Decision Making	MGMT-4850 Managing the High Perf. Org I
MGMT-4430 Marketing Principles	MGMT-4860 Managing the High Perf. Org II

⁴ This course can be fulfilled by taking a 2-credit course from a list of courses published at the start of each semester.

⁵ Students may select any two of the following courses to satisfy technical elective requirements:

DSES-4200 Design and Analysis of Work Systems	DSES-4260 Industrial Safety and Hygiene
DSES-4240 Engineering Project Management	DSES-4810 Computational Intelligence
DSES-4250 Facilities Design & Industrial Logistics	DSES-4280 Dec. Focused Systems Engineering

Certain graduate level DSES courses can also serve as technical electives for eligible undergraduates with permission of the instructor and the adviser.

⁶ May be taken in either fall or spring semester.

Electives

The free electives indicated above may be chosen from any academic discipline to broaden the student's educational background and/or develop greater depth in a selected discipline.

Humanities and Social Sciences Electives

The electives in this area are based on the Institute and School of Engineering requirements. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Special Undergraduate Opportunities

Cooperative Education Program

DSES encourages this option, which allows students to gain professional experience as part of the educational program. Additional information on co-op opportunities is included in the Educational Programs and Resources section of this catalog, as well as through the faculty adviser or the Career Development Center.

Graduate Programs

<http://www.dses.rpi.edu/programs/masters.cfm>

Master's Programs

The Department of Decision Sciences and Engineering Systems offers two master's level degrees, both of which can be earned within each of three curricula. These curricula and their individual requirements are described below.

Industrial and Management Engineering (IME) Curricula

Students can work toward either the M.S. degree, which requires a project or thesis, or the nonthesis M.Eng. degree. These IME degrees are also available through distance learning. Contact the Office of Professional and Distance Education for course scheduling information.

In general, all applicants to the IME master's programs must take the Graduate Record Exam (GRE). This requirement is especially important for those requesting financial aid, due to the large number of aid requests. However, for students applying to the M.Eng. program, the GRE may sometimes be waived. In special situations, and with departmental approval, the GMAT may be substituted for the GRE.

All students seeking either of the IME master's degrees must have completed the following two courses in their undergraduate program at Rensselaer or have had the equivalent courses elsewhere:

Applied Operations Research (equivalent to DSES-6610)

Introduction to Applied Statistics (equivalent to DSES-6110)

Both IME master's degrees require a minimum of 30 credit hours.

In addition to the above prerequisite courses, a student's core course work must include:

DSES-6470	Global Strategic Management of Technological Innovation	DSES-6620	Discrete Event Simulation
DSES-6500	Information and Decision Technologies for Industrial and Service Systems	DSES-6xxx	Applied Statistics Elective (One graduate course from those listed under the Applied Probability and Statistics and Quality Control concentration.)
DSES-6600	Models for Production Control and Service Logistics		

For students seeking the M.S. degree, three to nine of the 30 credit hours must be in DSES-6990 (Master's Thesis) or DSES- 6980 (Master's Project). The thesis or project credits can also count toward the nine-credit-hour (three-course) concentration that the program requires.

While the remainder of the program may be tailored to the student's interest, the Plan of Study must include a concentration area. The concentration is a set of three or more courses (or nine credit hours) that reflects a logical progression for developing a base of expertise in an area of study. Concentrations will usually, but not always, include at least one of the core courses listed above. Listed below are examples of both concentration areas and courses that can be within each area.

Applied Operations Research Concentration

DSES-4770	Mathematical Models of Operations Research
DSES-4780	Computational Optimization
DSES-6050	Stochastic Processes
DSES-6200	Models in Facilities Planning and Materials Handling
DSES-6210	Theory of Production Scheduling
DSES-6630	Continuous Simulation and Financial Mathematics
DSES-6760	Combinatorial Optimization and Integer Programming
DSES-6770	Linear Programming
DSES-6780	Nonlinear Programming
DSES-6820	Queuing Systems and Applications
DSES-6830	Large-Scale Systems: Case Studies and Analyses
DSES-6840	Modeling Large-Scale Systems
DSES-6860	Evaluation Methods for Decision Making
DSES-6890	Multiple Criteria Decision Making

Applied Probability and Statistics and Quality Control Concentration

DSES-4750	Probability Theory and Applications
DSES-4760	Mathematical Statistics
DSES-6010	Applied Regression Analysis
DSES-6020	Design of Experiments
DSES-6030	Sampling Methods
DSES-6040	Nonparametric Methods
DSES-6050	Stochastic Processes
DSES-6060	Applied Multivariate Analysis
DSES-6070	Statistical Methods for Reliability Engineering
DSES-6090	Decision Analysis
DSES-6100	Time Series Analysis
DSES-6140	Exploratory Data Analysis

DSES-6150	Advanced Probability for Statistical Inference
DSES-6170	Management of Quality Processes and Reliability
DSES-6180	Introduction to Knowledge Discovery with Data Mining
DSES-6230	Quality Control and Reliability

Information Systems Concentration

DSES-4810	Computational Intelligence
DSES-6220	Concurrent Engineering
DSES-6500	Information and Decision Technologies for Industrial and Service Systems
DSES-6520	Enterprise Database Systems
DSES-6530	Decision Support and Expert Systems
DSES-6550	Information Systems Analysis and Design
DSES-6560	Information Technology and Systems for Enterprise Engineering
DSES-6570	Information Technology and Systems for E-Business
DSES-6870	Introduction to Neural Networks

Management of Technology Concentration

MGMT-6690	Supply Chain Mgmt. for E-Business
MGMT-6960	Knowledge Based Operations Management
MGMT-6240	Financial Trading and Investment
MGMT-6490	Competitive Advantage and Operations Strategy
DSES-6470	Global Strategic Management of Technological Innovation
DSES-6480	Service Operations Management
DSES-6830	Large-Scale Systems: Case Studies and Analyses
DSES-6860	Evaluation Methods for Decision Making

Manufacturing Systems Concentration

DSES-4200	Design and Analysis of Work Systems
DSES-4250	Facilities Design and Industrial Logistics
DSES-6200	Models in Facilities Planning and Materials Handling
DSES-6210	Theory of Production Scheduling
DSES-6220	Concurrent Engineering
DSES-6230	Quality Control and Reliability
DSES-6560	Information Technology and Systems for Enterprise Engineering
DSES-6600	Models for Production Control and Service Logistics
DSES-6960	Management of Manufacturing Supply Chains

Service Systems Concentration

DSES-6480	Service Operations Management and at least two courses from the list below:
MGMT-4370	Risk Management
DSES-6170	Management of Quality Processes and Reliability
DSES-6860	Evaluation Methods for Decision Making
DSES-6980	Master's Project in Service Systems

Service and Manufacturing Systems Engineering Curricula

The Department of Decision Sciences and Engineering Systems offers the Master of Engineering and Master of Science degrees in Service and Manufacturing Systems Engineering. This program combines modeling, statistical, computer, design and management skills focused on the operations of service and manufacturing systems. The program core provides a skill base in operations engineering with a balance of applications in services and manufacturing. Course work concentrations allow specialization in Service Operations or Manufacturing Processes.

All applicants must take the Graduate Record Exam (GRE). GRE completion is especially important for those requesting financial aid, due to the large number of aid requests. The GMAT may be substituted for the GRE for students applying to the Master of Engineering program.

All students seeking the Master of Engineering or Master of Science degree in Service and Manufacturing Systems Engineering must complete the following course in their undergraduate program while at Rensselaer or have had the equivalent course work elsewhere:

DSES-6110 Introduction to Applied Statistics

The Master of Engineering and Master of Science degrees in service and manufacturing systems engineering are 30-credit-hour programs of study. The prerequisite course may be counted toward the 30-credit-hour total if taken at Rensselaer and included in the Master's Plan of Study.

In addition to the above prerequisite courses, a student's core course work will include:

DSES-6570	Information Technology and Systems for E-Business	DSES-6820	Queuing Systems and Applications
DSES-6610	Systems Modeling and Decision Sciences	MGMT-6960	Knowledge Based Operations Management
DSES-6620	Discrete Event Simulation		

Concentrations

Students must select the remaining 4 to 5 courses in the Plan of Study from either the Service Operations or Manufacturing Processes concentrations. These concentrations are summarized below:

Service Operations Concentration

DSES-6140	Exploratory Data Analysis	DSES-6860	Evaluation Methods for Decision Making
DSES-6180	Knowledge Discovery with Data Mining	DSES-6870	Introduction to Neural Networks
DSES-6470/MGMT-6610	Global Strategic Management of Technological Innovation	DSES-6990/6980	Master's Project in Service Systems
DSES-6480/MGMT-6480	Service Operations Management	MATH-4740	Mathematics of Finance
DSES-6630	Continuous Simulation and Financial Mathematics	MGMT-6240	Financial Trading and Investing
		MGMT-6690	Supply Chain Management for E-Business

Manufacturing Processes Concentration

DSES-6070	Statistical Methods for Reliability Engineering	DSES-6600	Models for Production Control & Service Logistics
DSES-6100	Time Series Analysis	DSES-6960	Management of Manufacturing Supply Chains
DSES-6170/MGMT-6470	Management of Quality Processes and Reliability	DSES-6990/6980	Master's Project in Manufacturing Systems
DSES-6200	Models for Materials Handling and Facility Design	MANE-6800	Manufacturing Systems Integration
DSES-6210	Theory of Production Scheduling	MGMT-6490	Competitive Advantage and Operations Strategy
DSES-6220	Concurrent Engineering		
DSES-6230	Quality Control and Reliability		

For students seeking the Master of Science degree, three to nine of the 30-credit-hour program must be taken under DSES-6990 (Master's Thesis in Service Systems or Master's Thesis in Manufacturing Systems) or DSES-6980 (Master's Project in Service Systems or Master's Project in Manufacturing Systems).

Operations Research and Statistics Curricula

In this curriculum, DSES offers M.S. and M.Eng. degree programs that combine course work in applied probability and statistics, optimization, modeling, and decision sciences in the scientific application of quantitative tools to support decision making. The scope of the programs includes the formulation, solution, and implementation of mathematical models of decision problems to measure, evaluate, and optimize system performance. Most students can complete either program in 30 credit hours. Any student planning to enroll in the DSES doctoral program should consult with the faculty adviser prior to making course selections.

The diversity of this curriculum's faculty enables these programs to encompass varied research topics. A student may work simultaneously on a master's degree in this program and on a degree in computer science, business administration, mathematics, computer and systems engineering, or another related area.

Most students participating in this curriculum hold a bachelor's or master's degree in engineering, mathematics, the physical sciences, business administration, or management. Students with training in other disciplines such as economics and the social sciences are also encouraged to apply if their quantitative backgrounds include the equivalent of at least three semesters of calculus and linear algebra.

All applicants are required to take the Graduate Record Examination (GRE) except under extenuating circumstances.

For the master's programs in operations research and statistics, no prerequisites are required. However, the following courses or their equivalents are required.

		Credit hours			Credit hours	
DSES-4640	Operations Research I	4	or	DSES-6820	Queuing Systems & Applications	3
and				and		
DSES-4750	Probability Theory & Applications. .	4		DSES-6620	Discrete-Event Simulation	3
and				and		
DSES-4760	Mathematical Statistics.....	4		DSES-6060	Applied Multivariate Analysis	3
and				or		
DSES-6050	Stochastic Processes.....	3		DSES-6140	Exploratory Data Analyses.....	3
or				and		
DSES-6150	Advanced Probability for Statistical Inference	3			Modeling Optimization Elective	3*

While the remainder of the program may be tailored to the student's interest, the Plan of Study must include a concentration area. The concentration is a set of three or more courses (or nine credit hours) that reflects a logical progression for developing a base of expertise in an area of study. Concentrations will usually, but not always, include at least one of the core courses listed above. Listed below are examples of both concentration areas and courses that can be within each area.

Quality and Reliability Concentration

DSES-6020	Design of Experiments
DSES-6050	Stochastic Processes
DSES-6070	Statistical Methods for Reliability Engineering
DSES-6150	Advanced Probability for Statistical Inference
DSES-6170	Management of Quality Processes and Reliability
DSES-6230	Quality Control and Reliability

Forecasting Concentration

ECON-6570	Econometrics
DSES-6010	Applied Regression Analysis
DSES-6060	Applied Multivariate Analysis
DSES-6100	Time Series Analysis
DSES-6130	Statistical Computing
DSES-6140	Exploratory Data Analysis
DSES-6150	Advanced Probability for Statistical Inference
DSES-6870	Introduction to Neural Networks

Decision Analysis Concentration

DSES-4750	Probability Theory and Applications
DSES-6090	Decision Analysis
DSES-6500	Information and Decision Technologies for Industrial and Service Systems
DSES-6530	Decision Support and Expert Systems
DSES-6830	Large-Scale Systems: Case Studies and Analyses
DSES-6860	Evaluation Methods for Decision Making
DSES-6890	Multiple Criteria Decision Making

Modeling/Optimization Concentration

DSES-4770	Mathematical Models of Operations Research
DSES-4780	Computational Optimization
DSES-6200	Models in Facilities Planning and Materials Handling
DSES-6210	Theory of Production Scheduling

* Any course listed under the Modeling/Optimization Concentration except DSES-4770.

DSES-6760	Combinatorial Optimization and Integer Programming
DSES-6770	Linear Programming
DSES-6780	Nonlinear Programming
DSES-6840	Modeling Large-Scale Systems
DSES-6870	Introduction to Neural Networks

Simulation Concentration

DSES-6630	Continuous Simulation and Financial Mathematics and at least two of the following courses:
DSES-6020	Design of Experiments
DSES-6050	Stochastic Processes
DSES-6100	Time Series Analysis
DSES-6150	Advanced Probability for Statistical Inference
DSES-6820	Queuing Systems and Applications
DSES-6870	Introduction to Neural Networks

Data Mining Concentration

DSES-4810	Computational Intelligence
DSES-6010	Applied Regression Analysis
DSES-6020	Design of Experiments
DSES-6030	Sampling Methods
DSES-6040	Nonparametric Methods
DSES-6060	Applied Multivariate Analysis
DSES-6100	Time Series Analysis
DSES-6130	Statistical Computing
DSES-6140	Exploratory Data Analysis
DSES-6180	Introduction to Knowledge Discovery with Data Mining
DSES-6870	Introduction to Neural Networks

Doctoral Programs

<http://www.dses.rpi.edu/programs/doctoral.cfm>

Students working toward the Ph.D. in DSES may choose to major in industrial engineering, information systems, service and manufacturing systems engineering, operations research, or statistics. Advanced research and a dissertation in the chosen field are required in the doctoral program. In addition, Ph.D. students must complete the following:

- Institute requirements established by the Office of Graduate Education.
- Seminar in DSES research: Doctoral students must complete DSES-6900 during the fall semester of the first academic year of residency. This course is intended to introduce the student to the research environment at Rensselaer and to provide background on the process of doctoral research in DSES. Another intent of the course is to develop the student's communication skills.
- Doctoral qualifying examination: The doctoral qualifying exam consists of two components — a written exam component and a research component. The written exam covers the core areas of DSES and the basis for this examination, including DSES-4530, DSES-4750, DSES-4760, DSES-4770, and

Information Systems Concentration

DSES-4810	Computational Intelligence
DSES-6500	Information and Decision Technologies for Industrial and Service Systems
DSES-6520	Enterprise Database Systems
DSES-6530	Decision Support and Expert Systems
DSES-6560	Information Technology and Systems for Enterprise Engineering
DSES-6620	Discrete-Event Simulation
DSES-6870	Introduction to Neural Networks

Financial Engineering Concentration

MATH-4200	Mathematical Analysis I
MGMT-4370	Risk Management
MATH-4740	Mathematics of Finance
DSES-6630	Continuous Simulation and Financial Mathematics
MGMT-6240	Financial Trading and Investment
DSES-6010	Applied Regression Analysis
DSES-6060	Applied Multivariate Analysis
DSES-6100	Time Series Analysis
DSES-6130	Statistical Computing

Marketing Research Concentration

DSES-6010	Applied Regression Analysis
DSES-6060	Applied Multivariate Analysis
DSES-6130	Statistical Computing
DSES-6520	Enterprise Database Systems

DSES-6500 or their equivalents. A more detailed description of this and other required examinations is available from the DSES doctoral program director.

- **Doctoral area requirement:** Doctoral students must register for and complete course work in a selected major area. See the DSES doctoral program director for detailed documentation of DSES doctoral area requirements.
- **Doctoral candidacy examination:** Each student must take an oral candidacy examination after passing the DSES area requirement but before completing 45 credit hours of graduate work beyond the Masters degree. This examination tests the candidate's background for the proposed research, appropriateness of the thesis research, and the ability of the candidate to successfully complete the research. The thesis research proposal must contain at least one result that meets journal publishing standards.
- **Doctoral dissertation and defense:** Each student must write a doctoral thesis and give a formal oral public defense.

Apart from the seminar in DSES research, doctoral area course requirements, and equivalent course material for the doctoral qualifying examination, there are no additional course requirements for the doctoral degree. However, the student is expected to develop in-depth knowledge in his/her dissertation area through appropriate course work, as well as supervised research. A Plan of Study is required, which must be approved by the thesis adviser and the DSES doctoral program director. Representative programs of study are available from the DSES doctoral program director.

Course Descriptions

Courses directly related to all Decision Sciences and Engineering Systems curricula are described in the Course Description section of this catalog under the department code DSES.

Electrical, Computer, and Systems Engineering

Department Head: Kenneth A. Connor

Director of Master's Programs: Yannick L. LeCoz

Director of Doctoral Programs: Alan A. Desrochers

Department Home Page: <http://www.ecse.rpi.edu/>

Electrical, computer, and systems engineers have long been at the forefront of new discoveries and their integration into advanced design and engineering methodologies. Inventions in areas such as integrated electronics and optical devices stimulate innovations in computers, control, and communications. New systems theory and mathematical techniques are then needed for analysis and design work.

As a broad-based department, Electrical, Computer, and Systems Engineering (ECSE) offers several advantages for undergraduate and graduate study. One is the ability to attack the many facets of modern problems that cut across disciplinary lines. Another is the flexibility for students to embark on individually tailored programs and for the department to launch new areas of research.

The department offers programs of study leading to bachelors, master's, and doctoral degrees in electric power engineering, electrical engineering, and computer and systems engineering. Each curriculum is

sufficiently flexible to accommodate a wide range of interests. The curriculum the student selects is determined by his or her specific interests and, in some cases, by directions within a field of interest.

Research and Innovation Initiatives

Communications, Information, and Signal Processing

Advanced study and research in this field deals with the encoding, transmission, retrieval, and interpretation of information. Students may pursue programs of study strong in mathematical foundations, or oriented more toward hardware and practical implementation, or a combination of both.

Communications research focuses on the transmission of information over wireless, optical, and wire channels. Link level concerns, such as modulation and coding, as well as local and wide area networks are considered. Two of the fundamental subdisciplines emphasized are statistical communications and telecommunications. The former considers special types of systems in different environments, typified by random signals in random channels, as in space communication. The latter includes the hardware and societal demands of telephone, wireless communications, cable television, communications networks (including ATM and ISDN), and other systems.

The area of information processing is concerned primarily with the theory and engineering design associated with interpreting and manipulating received data, primarily in discrete form. Major research topics include information theory, including rate distortion theory, along with the coding and compression of speech, image, and video signals. A quantitative understanding of the nature and meaning of information provides a theoretical foundation. A special research emphasis at Rensselaer is the application of image transmission and interpretation techniques to pattern recognition, image processing, digital video processing and compression coding, and speech recognition.

Signal processing considers the application of digital processing techniques to problems encountered in many areas, including biomedical instrumentation, control systems, and audio processing. Special laboratories are available for speech processing, video and image processing, networking, and communications

Computer Networking

Research focal areas in computer networking include network management, traffic management, congestion control, traffic engineering, quality-of-service (QoS) architectures, multimedia networking, network modeling, measurement, and performance analysis. The application areas include wired, wireless, ad-hoc, satellite networks, and pervasive computing. The networking group also participates in interdisciplinary research in control theory, economics, scalable simulation technologies, and video compression.

As world networks get increasingly complex, the need for automated network management and sophisticated traffic management capabilities becomes more urgent. The theoretical foundations for these areas are of immense interest. Moreover, the structure of the Internet in terms of thousands of ISPs demands new economic models and mechanisms to ensure continued investment and growth of Internet services. Network heterogeneity—especially in terms of wired, wireless, ad-hoc, and satellite—demands fundamental research for seamless interconnection. Rensselaer's modeling subgroup serves all areas in terms of self-similar and advanced stochastic models. Finally, newer applications with QoS capabilities need to be deployed on the Internet and to co-exist with the current applications. The computer network group works on all these areas using a mix of analysis, simulation, and experimental tools.

Computer Vision, Image Processing, Digital Media and Computational Geometry

Research in image processing covers a range of technologies and applications. This activity occurs at the Center for Image Processing Research (CIPR), the Center for Subsurface Sensing and Imaging Systems (CenSSIS), and the Center for Next Generation Video (CNGV), as well as the Document Analysis Laboratory (DocLab), Advanced Imaging Systems Laboratory, Computer Vision and Robotics Laboratory, and Intelligent Systems Laboratory.

Research areas include pattern recognition, computer vision, multidimensional and multimodality image analysis, image compression, biotech assay automation, eye tracking, optical scanning systems, artificial intelligence, graphics, computational geometry, and Internet image analysis services.

Application areas include systems biology, computer-assisted surgery, radiation treatment planning, medical image reconstruction, document image analysis, geographic information science, computational cartography, and image analysis aids to neurobiology. Additional application areas are bioinformatics, human fatigue monitoring, human computer interaction, video imagery activity interpretation, decision making under uncertainty, robot localization, robotic devices for automated scoring of assays for the biotechnology industry, and biological multidimensional microscopy.

The work of digital media includes such topics as image processing algorithms and architectures for digital cinema, advanced image compression and decompression algorithms, and methods for indexing video by content. Multimedia work also includes graphics courseware development for the World Wide Web using HTML, Java, PHP, my SQL, and VRML.

Computer Hardware, Architecture, VLSI and Mixed Signal Design

The design, implementation, layout, and testing of hardware systems constitutes a vital component of electrical and computer engineering research. Research areas include the design and testing of digital and mixed-signal chips in CMOS and BiCMOS and the development of computer-aided design tools for such designs. Specific topics include the development of high-speed computer chips using SiGe BiCMOS technology, the design and testing of mixed-signal chips for communications applications, the influence of 3-D integration on computer design, and the development of techniques for the design and reliable operation of digital chips fabricated in deep submicron CMOS.

This group has grown significantly in recent years. New faculty activities include error correcting coding system design and VLSI implementation for magnetic and holographic storage, and fiber and wireless communication; algorithm/architecture co-design for wireless multi-antenna signal processing; fault tolerance for semiconductor memories and molecular nanoelectronic memory; signal processing algorithm/architecture co-design for defect/variation tolerance in end-of-the-roadmap CMOS and post-silicon nanoelectronics regimes; silicon-based radio-frequency power amplifiers; multi-Gb/s broadband communications circuits; wafer-level 3-D integration for millimeter-wave smart antenna transceivers; RF-powered wireless communication circuits for bio-implantable microsystems; devices, circuits, systems, algorithms and methodologies to enable inexpensive portable platforms for environmental and biomedical diagnostics; detection and quantification of low levels of biological signals reliably, conveniently, safely and quickly.

Control, Robotics, and Automation

Current research projects address both control theory and a variety of applications. Faculty interests include advanced control algorithms development in the areas of nonlinear control, adaptive control, multivariable control, robust control, distributed control, and optimal control. These algorithms are applied to robotics, automation systems, robotic multi-vehicle coordination, power generation and transmission systems, power electronics, networked systems, micro and nano-systems, and discrete-event systems.

Research in robotics and automation is inherently inter-disciplinary. ECSE Faculty in this area coordinates closely with MANE, Computer Science, and Cognitive Science departments for joint research and curriculum development. Current projects include planning and control for advanced manufacturing systems, multi-robot actuator and sensor networks for coordinated monitoring and manipulation, and precision motion and force control with vision guidance in micro and nano assembly and manufacturing. Extensive experimental and computational facilities, as well as undergraduate and graduate research opportunities, are available in the New York State Center for Automation and Technology Systems.

Current research topics in nonlinear control include the development of robust and adaptive design tools which systematically account for model uncertainty and unavailable state information. Another area of interest is nonlinear control of large-scale interconnected systems (communication and power networks, vehicle formations, etc.) with limited, local information available to each component of the system. New design techniques are being developed that exploit the input/output properties of these components and achieve the design objectives of stability, decentralization and robustness.

Discrete-event systems theory is a modeling and control discipline relevant to computer-communication systems, transportation systems as well as the modeling and control of automated manufacturing systems. These systems are characterized by concurrent and asynchronous operations, resource allocation issues, deadlock detection and avoidance, all in a random environment. Petri nets, multi-agent systems and holonic control systems techniques are being developed to design, model, analyze, control, and evaluate the performance of such interconnected systems.

Electric Power, Power Electronics, Plasma Science, and Electromagnetics

Current research is concentrated in electric and magnetic field computation, electrical transients and switching technology, dielectrics and insulation systems, power system analysis and optimization, semiconductor power electronics and fusion plasma diagnostics.

The design of equipment to minimize losses, achieve compaction, or better utilize material frequently requires a sound knowledge of the electric and magnetic field configurations involved. Several projects in the recent past have adapted finite element methods to the solution of current problems in large machines.

A new approach to digital field computations is being devised, based on techniques used to solve large network problems. The objective is to develop a more efficient, computationally conservative method. In today's energy-scarce world, there is a great emphasis on building more efficient electrical equipment.

Projects are under way in the magnetic fields area to better understand the mechanism of electrical losses in rotating machinery and power transformers, with the ultimate goal of reducing these losses. The modeling of transients in transformer structures could also provide insight into the problems of both design and operation. The techniques being developed are finding applications in new areas such as superconducting fault current limiting devices. This area of endeavor also includes the fundamental processes of switching large currents and the attendant system interactions.

An electrical insulation system, be it solid, liquid, gaseous, or a combination of these, is an essential part of all power equipment. Current research seeks to better understand the fundamental behavior of insulation under a variety of operating conditions and to develop diagnostic instrumentation, particularly for large generators. This involves experimentation and computer modeling in the areas of discharge physics, electrostatic phenomena, and high-voltage technology. The recent development of nanodielectric structures for use as high-voltage insulation is showing particular promise with substantial property enhancements.

Optimization theory is used in the design of electric power systems to obtain high efficiency at minimum cost, particularly for systems that involve distributed generation. This has been extended to include the development of intelligent protective relaying for dealing with the problem of islanding and utilizes the department's hybrid system simulator and Electromagnetic Transient Program (EMTP) studies.

Power electronics plays a critical role in ensuring energy security and achieving high energy efficiency. It is essential for the integration of renewable energy sources such as wind, solar, and fuel cell, and is a critical enabler for energy-efficient technologies including solid-state lighting and variable-speed motor drives. Power electronics-based FACTS (flexible ac transmission systems) devices increase the transmission capacity of electric power grids and improve their stability and power quality. Power electronics is also at the

center of new power technologies for vehicular applications such as hybrid electric vehicles and next-generation passenger airplanes. Efficiency, size, reliability, cost, and system compatibility are the primary drivers for these applications which must be addressed in an integrated manner to maximize system benefits. Rensselaer has identified this growing area of interest and is currently investigating future solutions to these challenging problems. Work in this multidisciplinary field requires an understanding of semiconductor devices, circuit theory, signal analysis, analog and digital control, magnetics, and heat transfer. At Rensselaer, these fields are applied to electronic energy conversion, motion control, and system integration for the electric power, aerospace, information technology, and industrial automation industries. Current interests include wind and fuel cell power integration, monolithic power management solutions for microprocessors, efficient ac-dc and dc-dc power conversion for IT applications, integrated multilevel modeling and analysis of complex power electronics systems, and energy-efficient power architectures for residential and commercial buildings.

With the continual improvement of power semiconductor devices over the last thirty years, it is now possible to convert electrical energy from one form to another efficiently and accurately. Work in this multidisciplinary field requires an understanding of semiconductor devices, circuit theory, signal analysis, analog and digital control, magnetics, and heat transfer. At Rensselaer, these fields are applied to electronic energy conversion and motion control for the electric power and industrial automation industries. Current interests include propulsion systems for electric vehicles, generation systems for wind turbines, the use of artificial intelligence (fuzzy logic, genetic algorithms, and neural networks) in the design and control of electric power conversion and electric machines, and the adaptive control of electric machines.

Plasma engineering has played a fundamental role in electrical engineering throughout the history of this discipline. High-temperature plasma research is crucial to the development of a controlled thermonuclear fusion energy source. Rensselaer's Plasma Dynamics Laboratory has a very active research program on the development of particle beam diagnostic systems for magnetically confined plasma experiments. Specific diagnostic techniques are developed and tested on relatively small-scale experiments in the on-campus laboratory. Techniques are then scaled up and applied on major confinement experiments located at other U.S. universities (e.g., the Universities of Texas and Wisconsin), at U.S. national laboratories (e.g., Oak Ridge National Lab and Lawrence Livermore National Lab), and foreign institutions (e.g., the Japanese National Institute for Fusion Science and the Max-Planck Institute in Greifswald, Germany).

Microelectronics and Photonics Technology

Advanced study and research include semiconductor devices for high-power, high-frequency, and optoelectronics applications, epitaxial and bulk growth of novel semiconductor materials and device structures, and the use and development of simulation and modeling tools for microelectronics and photonics device design.

An extensive micro and nano fabrication clean room in the Center for Integrated Electronics (CIE) is equipped with up to 8" wafer tools for end-to-end device fabrication, characterization, metrology, and testing of silicon-based devices and integrated circuits, and an array of equipment for compound semiconductor device processing. Research in this area focuses on novel device technology and process development, advanced electrical and optical interconnect processing, three dimensional hyper-integration, and the fabrication of micromechanical structures and microsystems. The recently acquired nanolithography tools, including nanoimprint, nano ink, and direct Ebeam writer enable microelectronic and photonic device fabrication at feature size of 10 nm.

The microelectronics and photonics group has several specialized laboratories equipped to meet industrial standards for advanced research techniques. The electronic materials laboratory includes several state-of-the-art bulk crystal growth systems, wafer slicing and chemical mechanical polishing facilities, liquid phase epitaxy system for multilayer hetero-epitaxial growth, and cold wall epitaxial reactors for the

growth of single crystal III-V, IV-IV and II-VI semiconductors. Associated diagnostic equipments for structural, optical and electrical characterization of semiconductors are also available.

The high-voltage power device laboratory, as part of the NSF-sponsored Center for Power Electronics Systems (CPES) at RPI, has equipment that can measure semiconductor power devices in wafer and package form up to 20000 V and 25 A. The equipment includes a Sony/Tektronix 370A curve tracer, an HP 4155 parameter analyzer with a high power module, three Bertan power supplies, several Keithley voltage/current source measurement units, custom high-voltage rectifier, GTO and IGBT switching circuits, a 500 MHz digitizing oscilloscope, a Delta 9023 furnace, and manual and semi-automatic probe stations with high-temperature controller and chuck for device characterization.

The semiconductor device characterization laboratories are equipped for carrying out comprehensive electrical characterization of semiconductor devices. Automated measurement systems are available for CV and IV measurements and deep level transient spectroscopy. Facilities are available for cryogenic measurements of semiconductor devices at liquid nitrogen and helium temperatures.

The laboratories of the Future Chips Constellation include state-of-the-art metal-organic chemical-vapor deposition (MOCVD) for the epitaxial growth of III-V nitride materials and an array of advanced materials characterization tools. Light-emitting diodes that have advanced device architectures, emitting in the visible and ultra-violet spectrum, are routinely grown, processed, and evaluated.

Research in association with the Focus Center - New York (FC-NY), which is part of the national Interconnect Focus Center (IFC), addresses the discovery and invention of new solutions that will enable the U.S. semiconductor industry to transcend known limits on interconnects that would otherwise decelerate or halt the rate of progress toward gigascale integration.

Also under investigation is a new regime of transistor operation in the terahertz range using the excitation and rectification of plasma waves in the transistor channel. This work is supported by modeling and parameter extraction based on our circuit simulator, AIM-Spice (with tens of thousands users world wide) and by materials and device research on multifunctional semiconductors having pyroelectric properties.

Within the ECSE Department and the Center for Integrated Electronics are numerous Sun workstations with a variety of commercial design and simulation software, presently including Cadence, Mentor, TMA, and Hewlett-Packard software suites. Research programs developing supplemental design tools for modeling integrated circuits, devices, processes, and interconnects have provided unique supplemental capabilities.

Faculty*

Professors

Bhat, I.—Ph.D. (Rensselaer Polytechnic Institute); solid state, electronic materials.

Chow, J.H.—P.E., Ph.D. (University of Illinois); large-scale system modeling, multivariable control systems.

Chow, T.P.—Ph.D. (Rensselaer Polytechnic Institute); semiconductor device physics and processing technology, integrated circuits.

Connor, K.A.—Ph.D. (Polytechnic Institute of New York); electromagnetic theory, wave propagation, plasmas for fusion research and industrial applications, finite element methods.

Degenoff, R.C.—P.E., D.Eng. (Rensselaer Polytechnic Institute); transient voltages in electrical machines and transformers, HVDC system design and electric utility system planning.

Desrochers, A.A.—Ph.D. (Purdue University); discrete event dynamic systems, robotics, automated manufacturing systems control.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting.

- Gerhardt, L.A.**—Ph.D. (State University of New York at Buffalo); communication systems, digital voice and image processing, adaptive systems and pattern recognition, integrated manufacturing.
- McDonald, J.F.**—Ph.D. (Yale University); communication theory, coding and switching theory, computer architecture, integrated circuit design, high frequency packaging, digital signal processing.
- Nagy, G.**—Ph.D. (Cornell University); pattern recognition, document-image analysis, optical character recognition, geometric computation, computer-mediated learning, computer vision.
- Nelson, J.K.**—C.Eng., Ph.D. (University of London); dielectrics and insulation systems, computer-based diagnostics, electrostatic phenomena.
- Pearlman, W.A.**—Ph.D. (Stanford University); information theory and source coding; image, video, and audio compression; digital image and signal processing.
- Roysam, B.**—D.Sc. (Washington University); intelligent imaging at low SNR, parallel computation, biomedical applications.
- Salon, S.J.**—P.E., Ph.D. (University of Pittsburgh); machine design, system component modeling and simulation.
- Sanderson, A.C.**—Ph.D. (Carnegie Mellon University); robotics, knowledge-based systems, computer vision.
- Schubert, E.F.**—Ph.D. (University of Stuttgart); compound semiconductor devices and materials, light emitting diodes, heterobipolar transistors, semiconductor device physics, solid state lighting.
- Shur, M.S.**—D.Sc. (Ioffe Institute); semiconductor materials and devices, integrated circuit simulation, characterization and design.
- Tien, J.M.**—Ph.D. (Massachusetts Institute of Technology); systems modeling, queuing theory, public policy and decision analysis, computer performance evaluation, information systems, expert systems, computational cybernetics.
- Vastola, K.S.**—Ph.D. (University of Illinois); computer and communication networks.
- Wen, J.T.**—Ph.D. (Rensselaer Polytechnic Institute); nonlinear control, robot control, flexible structures control, deformation processes control.
- Woods, J.W.**—Ph.D. (Massachusetts Institute of Technology); digital signal processing, image processing, digital image and video compression.
- Wozny, M.J.**—Ph.D. (University of Arizona); computer graphics, computer-aided design, digital simulation, rapid prototyping systems.
- Zhang, X.-C.**—Ph.D. (Brown University); ultrashort optical pulse spectroscopy, terahertz lasers.

Associate Professors

- Dutta, P.S.**—Ph.D. (Indian Institute of Science); compound semiconductor materials and devices, crystal growth and substrate engineering, semiconductor quantum dots and nano-particles, photovoltaics, optoelectronics and microelectronics technologies.
- Franklin, W.R.**—Ph.D. (Harvard University); computational geometry, graphics and CAD applications, large geometric databases, geographic information systems, terrain visibility and compression.
- Ji, Q.**—Ph.D. (University of Washington); computer vision, image processing, pattern recognition, robotics.
- Kalyanaraman, S.**—Ph.D. (Ohio State University); ATM and Internet traffic management, multimedia networking, IP telephony, performance analysis, Internet pricing.
- LeCoz, Y.L.**—Ph.D. (Massachusetts Institute of Technology); numerical methods, random-walk algorithms for thermal and electromagnetic analysis of IC interconnects, quantum theory of semiconductor heterojunctions.
- Saulnier, G.J.**—Ph.D. (Rensselaer Polytechnic Institute); circuits and electronics, communication systems, digital signal processing.
- Schoch, P.M.**—Ph.D. (Rensselaer Polytechnic Institute); plasma diagnostics, instrumentation, engineering education.

Sun, J.—Ph.D. (University of Paderborn); power electronics and energy systems.

Xiang, N.—Ph.D. (Ruhr-University Bochum); signal processing, acoustic sensing, and architectural acoustics.

Assistant Professors

Abouzeid, A.A.—Ph.D. (University of Washington); packet networks.

Arcak, M.—Ph.D. (University of California, Santa Barbara); design and analysis of nonlinear control systems, adaptive control, applications to mechanical systems.

Hella, M.—Ph.D. (Ohio State University) RF and mixed signal VLSI circuits for wireless/optical transceivers; analog/RFIC design for bio-medical applications

Huang, W.—Ph.D. (Carnegie Mellon University); robotic manipulation, mobile robotics.

Huang, Z. R.—Ph.D. (Georgia Institute of Technology) optoelectronic device/microsystem design, fabrication and packaging.

Kar, K.—Ph.D. (University of Maryland); routing and traffic management in computer networks, congestion control and fair resource allocation, ad-hoc and sensor networks.

Mercado, A.V.—Ph.D. (University of Maryland); wireless communication.

Parsa, L.—Ph.D. (Texas A&M University) power electronics, energy conversion and motion control.

Radke, R.J.—Ph.D. (Princeton University); image and video processing.

Salama, K.N.—Ph.D. (Stanford University); mixed signal circuits for sensors, VLSI architectures for bio applications.

Sikdar, B.—Ph.D. (Rensselaer Polytechnic Institute); computer networks.

Yazici, B.—Ph.D. (Purdue University); inverse problems in biomedical imaging, tomography, diffuse optical tomography, biomedical optics, free space optical communications, ultrasonics, statistical pattern recognition theory and application.

Zhang, T.—Ph.D. (University of Minnesota); VLSI signal processing, error-correcting coding.

Clinical Professor

Murtuza, S.—Ph.D. (Purdue University); engineering education.

Research Associate Professors

Lu, J.—Ph.D. (Technical University of Munich); electronic materials.

Millard, D.L.—Ph.D. (Rensselaer Polytechnic Institute); microelectronics design and manufacturing, nondestructive testing and evaluation, instrumentation systems, multimedia development.

Research Assistant Professors

Azimi-Sadjadi, B.—Ph.D. (University of Maryland); stochastic systems, control, communication.

Demers, D.—Ph.D. (Rensselaer Polytechnic Institute); fusion plasmas, plasma diagnostics.

Gessmann, T.—Ph.D. (University of Stuttgart); condensed matter, wide bandgap semiconductors.

Adjunct Faculty

Anderson, T.R.—Ph.D. (New York University); electromagnetic theory, antennas, electromagnetic compatibility.

Bonissone, P.P.—Ph.D. (University of California, Berkeley); theory of fuzzy sets.

Bonner, S.J.—Ph.D. (Rensselaer Polytechnic Institute); robotics.

Caola, R.J.—M.E. (Rensselaer Polytechnic Institute); protective relaying.

Citriniti, T.D.—M.S. (Rensselaer Polytechnic Institute); computer graphics and visualization.

Hershey, J.E.—Ph.D. (Oklahoma State University); communication systems, cryptography, intellectual property management.

Kraft, R.P.—Ph.D. (Rensselaer Polytechnic Institute); digital control and manufacturing systems.

Marwali, M.K.—Ph.D. (Illinois Institute of Technology); power transmission and generators.

Prabhakara, F.S.—Ph.D. (Purdue University); power systems.

Sivasubramanian, K.—Ph.D. (Rensselaer Polytechnic Institute); electromagnetics, machines.

Thomenius, K.D.—Ph.D. (Rutgers University); imaging science.

Torrey, D.A.—P.E., Ph.D. (Massachusetts Institute of Technology); semiconductor power electronics, electric machinery.

Yuksel, M.—Ph.D. (Rensselaer Polytechnic Institute); computer networks, Internet pricing, routing in wireless networks, large-scale network simulation.

Emeritus Faculty

Borrego, J.M.—P.E., Sc.D. (Massachusetts Institute of Technology); semiconductor device physics and characterization, solar cells, application of microwaves.

Carlson, A.B.—Ph.D. (Stanford University); communication systems, circuits and electronics, educational methods, social context of engineering.

Close, C.M.—Ph.D. (Rensselaer Polytechnic Institute); network analysis and synthesis, control systems.

Das, P.K.—Ph.D. (University of Calcutta); microwave acoustics, solid-state devices, integrated circuits.

DiCesare, F.—Ph.D. (Carnegie Mellon University); discrete event systems, Petri net theory and applications manufacturing automation and integration, traffic control.

Frederick, D.K.—Ph.D. (Stanford University); automatic control, process modeling and control, computer simulation.

Ghandhi, S.K.—Ph.D. (University of Illinois); solid-state materials and devices, integrated circuits, device technology and electronic circuits.

Gutmann, R.J.—Ph.D. (Rensselaer Polytechnic Institute); solid-state devices, microwave techniques, and interconnection technology.

Greenwood, A.N.—Ph.D. (University of Leeds); electrical transients, interrupting devices.

Hickok, R.L., Jr.—Ph.D. (Rensselaer Polytechnic Institute); gaseous electronics, plasmas, energy conversion.

Jennings, W.C.—Ph.D. (Rensselaer Polytechnic Institute); plasma diagnostics, electronics manufacturing, multimedia educational materials.

Kelley, R.B.—Ph.D. (University of California, Los Angeles); methods to give machines smart behaviors, sensor-based automation/robotic systems, teaching methods.

Norvik, E.J.—M.E.E. (Rensselaer Polytechnic Institute); antennas, radio engineering, electronic circuits.

Rose, K.—Ph.D. (University of Illinois); semiconductor and superconductor materials and processing, VLSI design and testing.

Saridis, G.N.—Ph.D. (Purdue University); intelligent control systems, pattern recognition, computer systems, robotics, prostheses.

Savic, M.—Eng.Sc.D. (University of Belgrade); signal processing, biomedical electronics, electronics.

Saxena, A.N.—Ph.D. (Stanford University); solid-state materials, devices, integrated circuits, and advanced technologies.

Senior Research Engineer

Schatz, J.G.—A.A.S. (Hudson Valley Community College); vacuum and electronic systems.

Undergraduate Programs

Objectives of the Undergraduate Curriculum

Graduates of the programs within Electrical, Computer, and Systems Engineering will be prepared to:

- Obtain entry-level engineering positions in industry and/or admission to graduate study programs in their areas of interest.
- Establish themselves as problem-solvers and innovators, having a solid foundation in electrical, computer and systems, or electric power engineering and the ability to apply this background to solve real-world problems.
- Function effectively in a professional environment, having the necessary communication and leadership skills and the ability to view their own work in a broader context.
- Continue to develop professionally through life-long learning.

Baccalaureate Programs

Within this department, students may obtain the Bachelor of Science degree in three disciplines, electrical engineering, computer and systems engineering, or electric power engineering. The department also encourages students to consider graduate study in any of these three curricula. A professional program option, which leads to both the B.S. and M.Eng. degree, is also open to qualified students.

Engineering design is introduced and developed in the required courses ENGR-2050, ENGR-2350, and ECSE-2610, and in various electives. These courses set the stage for capstone design experience in the design elective, a writing-intensive course that satisfies the Institute writing requirements.

The following program descriptions indicate course schedules for students who select any of the three ECSE disciplines as their chosen field of study. However, various arrangements can be made with the help of an adviser. In all cases, adviser approval of individual plans of study is necessary to ensure satisfaction of departmental and accreditation requirements. The adviser must also approve in writing any exceptions to the courses specified in the descriptions below.

All three of the ECSE curricula require completion of a minimum of 128 credit hours. Within all of these program areas, the Pass/No Credit option may be used only for humanities and social sciences electives (up to a maximum of six credits) or free electives. All other courses used to satisfy the degree requirements must be taken on a graded basis.

Electrical Engineering Curriculum

Traditionally the largest and most diverse in all of engineering, this curriculum offers courses with various degrees of emphasis on theory, design, experimental work, and computer simulation. Subject matter ranges from semiconductors and electromagnetics to circuits and electronics, and to large-scale control, computer, communication, and information processing systems.

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1200	Eng. Graphics and CAD ¹	1
ENGR-1310	Intro. to Eng. Electronics ^{1,2}	1	MATH-1020	Calculus II	4
CSCI-1100	Computer Science ³	4	CHEM-1100	Chemistry I.....	4
MATH-1010	Calculus I.....	4	PHYS-1100	Physics I.....	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4

Second Year

Fall		Credit hours	Spring		Credit hours
ENGR-2050	Intro. to Engineering Design	4	ENGR-2350	Embedded Control	4
MATH-2400	Intro. to Differential Equations	4	ECSE-2010	Electric Circuits	4
PHYS-1200	Physics II.....	4	ECSE-2610	Computer Components and Operations ³	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4

Third Year

Fall		Credit hours	Spring		Credit hours
ECSE-2050	Intro. to Electronics	4	ECSE-2100	Fields and Waves I	4
ECSE-2410	Signals and Systems	4	ECSE-2210	Microelectronics Technology	4
MATH-2010	Multivar. Calc. and Matrix Alg. ¹	4		Free Elective ^{1,4,7}	3-4
	Hum. or Soc. Sci. Elective ¹	4		Multidisciplinary Elective ¹	4

Fourth Year

	Credit hours
ECSE-4500	Probability for Engineering Applications ¹
	Professional Development II ^{5,6}
ENGR-4010	Professional Development III
	Laboratory Elective
	Design Elective
	Restricted Elective
	Free Electives (2 or 3) ⁴
	Concentration Electives (2)

¹ May be taken either term.

² May be replaced by ENGR-1300.

³ Students entering this program in the fourth term should take CSCI-1100 in the spring, deferring ECSE-2610.

⁴ The free electives must total at least 12 credits.

⁵ This course will be fulfilled from a list published at the start of each semester.

⁶ May be taken in the third year.

⁷ Students are encouraged to select a life science course, such as BIOL-1010.

Humanities or Social Sciences Electives

In this area, electives are based on the Institute and School of Engineering requirements. Additionally, at least one course must be selected from the list posted on the ECSE home page. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Restricted Elective

Any course with the designation EPOW, ECSE, or ENGR-4xxx.

Laboratory Electives

ENGR-4710	Advanced Manufacturing Laboratory I (Fall)
EPOW-4030	Electric Power Engineering Laboratory (Spring)
ECSE-4220	VLSI Design (Fall)
ECSE-4690	Experimental Networking (Fall)
ECSE-4760	Computer Applications Laboratory (Spring)
ECSE-4770	Computer Hardware Design (Fall)

Multidisciplinary Electives

ENGR-1600	Materials Science for Engineers
ENGR-2090	Engineering Dynamics
ENGR-2250	Thermal and Fluids Engineering I
ENGR-2530	Strength of Materials

Design Electives

Design electives can be described as “multidisciplinary” (ECSE-4900) or “depth of understanding.” Students should visit the ECSE homepage for help with design elective selection.

ECSE-4900	ECSE Design (Fall and Spring)	ECSE-4780	Advanced Computer Hardware Design (Spring)
ECSE-4120	Electronic Circuits Design (Spring)	ECSE-4790	Microprocessor Systems Design (Fall)
ECSE-4260	Physical Design of Microelectronics (Spring)	ECSE-4980	Senior Design Project (Fall or Spring)
ECSE-4460	Control Systems Design (Spring)	MANE-4220	Inventor’s Studio (Fall and Spring)
ECSE-4560	Signal Processing Design (Spring)	EPOW-4850	EPE Design (Spring)

Concentration Electives

Two courses in one of the concentration areas. See the ECSE homepage for areas and courses.

Computer and Systems Engineering Curriculum

This field is one of the fastest-growing branches of engineering. Strong course sequences in software, hardware, and systems engineering are available. Students consider the digital computer as a system in itself, as a tool for modeling and design, and as an online element within a real-time system. There is the flexibility to study in depth automatic control, communications, or information processing, in addition to computer software, systems, and hardware.

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1200	Eng. Graphics and CAD ¹	1	MATH-2800	Intro. to Discrete Structures	4
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1310	Intro. to Eng. Electronics ^{1,2}	1
MATH-1010	Calculus I.....	4	MATH-1020	Calculus II	4
CSCI-1100	Computer Science I ³	4	CSCI-1200	Computer Science II ³	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4

Second Year

Fall		Credit hours	Spring		Credit hours
ENGR-2350	Embedded Control ³	4	ECSE-2660	Computer Architecture, Networks, and Operating Systems ³	4
ECSE-2610	Computer Components and Operations ³	4	MATH-2400	Intro. to Differential Equations	4
CSCI-2300	Data Structures and Algorithms ³	4	PHYS-1200	Physics II.....	4
PHYS-1100	Physics I.....	4	CHEM-1100	Chemistry I.....	4

Third Year

Fall		Credit hours	Spring		Credit hours
ENGR-2050	Intro. to Engineering Design.....	4	ECSE-2410	Signals and Systems	4
ECSE-2010	Electric Circuits	4		Software Engineering Elective ¹	3-4
	Multidisciplinary Elective ¹	4		Free Elective ^{1,4,7}	3-4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4

Fourth Year

	Credit hours	
	Professional Development II ^{5,6}	2
ECSE-4500	Probability for Engineering Applications ¹	4
ENGR-4010	Professional Development III.....	1
	Design Elective	3
	Restricted Elective	3-4
	Free Electives (2 or 3) ⁴	8-9
	Concentration Electives.....	6-8
	Hum. or Soc. Sci. Elective	4

¹ May be taken either term

² May be replaced by ENGR-1300

³ Students entering this program in the fourth term should take CSCI-1100 and ENGR-2350 in the spring deferring ECSE-2610, ECSE-2660, CSCI-1200, and CSCI-2300.

⁴ The free electives must total at least 12 credits.

⁵ This course will be fulfilled from a list published at the start of each semester.

⁶ May be taken in the third year.

⁷ Students are encouraged to select a life science course, such as BIOL-1010.

Humanities or Social Sciences Electives

In this area, electives are based on the Institute and School of Engineering requirements. Additionally, at least one course must be selected from the list posted on the ECSE home page. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Restricted Elective

Any course with the designation ECSE, CSCI, or ENGR-4xxx.

Software Engineering Electives

(Spring)

ECSE-4690	Experimental Networking (Fall)
ECSE-4750	Computer Graphics (Fall or Spring)
ECSE-6770	Software Engineering I (Fall)
CSCI-4380	Database Systems (Fall or Spring)
CSCI-4440	Software Design and Documentation (Fall or Spring)
CSCI-4600	The Human-Computer Interface

Design Electives

Design electives can be described as “multidisciplinary” (ECSE-4900) or “depth of understanding.” Students should visit the ECSE homepage for help with design elective selection.

ECSE-4900	ECSE Design (Fall and Spring)	ECSE-4780	Advanced Computer Hardware Design (Spring)
ECSE-4120	Electronic Circuits Design (Spring)	ECSE-4790	Microprocessor Systems Design (Fall)
ECSE-4260	Physical Design of Microelectronics (Spring)	ECSE-4980	Senior Design Project (Fall or Spring)
ECSE-4460	Control Systems Design (Spring)	ENGR-4060	Inventor’s Studio (Fall and Spring)
ECSE-4560	Signal Processing Design (Spring)	EPOW-4850	EPE Design (Spring)

Concentration Electives

Two courses in one of the concentration areas. See the ECSE homepage for areas and courses.

Electric Power Engineering Curriculum

The traditional place for electric power studies in a university is in the electrical engineering program, where the power option is offered as one of several concentrations. At Rensselaer, electric power is a separate degree program with its own faculty. It maintains strong ties to industry and is dedicated to preparing students for careers in power generation, delivery, or equipment; power electronics applied to drives and power conditioning; or at the intersection of electric power, economics, and management.

The vital role that energy plays in our lives has become increasingly evident in recent years. Society as we know it cannot function without an abundant supply of energy. It turns the wheels of industry and agriculture, it provides transportation, it supplies many of our domestic and recreational needs. There is continuing controversy over the primary source of the energy, but there is widespread agreement that electrical energy, because of its ease of transformation to and from other energy forms and its ease of transmission, distribution, and utilization, is vital. It is expected that electrical energy will constitute an increasing portion of the total energy used.

To keep pace with expanding needs through the development of ever more sophisticated systems requires the technical talent, scientific knowledge, mature judgment, and visionary innovation of the best

engineering minds of this generation. The electric power engineering program at Rensselaer is dedicated to meeting this need in generation, delivery, and utilization in an increasingly competitive environment. Study at Rensselaer is supported by the power industry, which the program serves. In particular, the ECSE Department operates a Grainger Scholar program under the auspices of the Grainger Foundation for well-qualified U.S. students.

First Year

Fall

	Credit hours
MATH-2400 Calculus I.....	4
CHEM-1100 Chemistry I.....	4
ENGR-1100 Intro. to Engineering Analysis.....	4
ENGR-1200 Eng. Graphics and CAD ²	1
Hum. or Soc. Sci. Elective ¹	4

Spring

	Credit hours
MATH-1020 Calculus II.....	4
ENGR-1600 Materials Science for Engineers.....	4
PHYS-1160 Physics I.....	4
ENGR-1300 Engineering Processes ^{2,3}	1
Hum. or Soc. Sci. Elective ¹	4

Second Year

Fall

	Credit hours
MATH-2400 Intro. to Differential Equations.....	4
PHYS-1200 Physics II.....	4
ENGR-2050 Intro. to Engineering Design.....	4
Hum. or Soc. Sci. Elective ¹	4

Spring

	Credit hours
ECSE-2010 Electric Circuits.....	4
MANE-4050 Modeling and Control of Dynamic Systems.....	4
ENGR-2600 Modeling and Analysis of Uncertainty.....	3
CSCI-1190 Beginning C Programming for Engineers.....	1
Hum. or Soc. Sci. Elective ¹	4

Third Year

Fall

	Credit hours
ENGR-4300 Electronic Instrumentation.....	4
ECSE-2100 Fields and Waves I.....	4
ENGR-2250 Thermal and Fluids Engineering I.....	4
EPOW-4010 Power Engineering Fundamentals.....	4

Spring

	Credit hours
ECSE-2410 Signals and Systems.....	4
EPOW-4020 Electromechanics.....	3
ENGR-2350 Embedded Control.....	4
Elective ⁷	4
Professional Development II ⁶	2

Fourth Year

Fall

	Credit hours
EPOW-4080 Semiconductor Power Electronics.....	3
Technical Elective ⁴	3
Hum. or Soc. Sci. Elective ¹	4
Elective.....	4

Spring

	Credit hours
EPOW-4850 Electric Power Eng. Design.....	3
EPOW-4030 EPE Laboratory.....	4
Elective.....	4
Technical Elective ⁴	3
ENGR-4010 Professional Development III ⁵	1

¹ There should be a total of 20 credit hours of H&SS electives.

² These required courses may be taken in any order.

³ May be replaced by ENGR-1310.

⁴ Any course in engineering or science that is at the 2000 level or higher.

⁵ Can be taken in either semester during senior year.

⁶ This course will be fulfilled from a list published at the start of each semester.

⁷ Students are encouraged to select a life science course, such as BIOL-1010.

Humanities or Social Sciences Electives

In this area, electives are based on the Institute and School of Engineering requirements. Additionally, at least one course must be selected from the list posted on the ECSE home page. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Concentration in Power Electronics Systems

The concentration in Power Electronics Systems is open to all students in Electric Power Engineering. Fulfillment of the concentration will be recognized by the department and consists of both the following courses:

EPOW-4080 Semiconductor Power Electronics Systems
 EPOW-4850 Electric Power Engineering Design (with Power Electronics emphasis)

and one of the following:

ECSE-4250 Integrated Circuit Processes and Design
 ECSE-4290 Electronic Packaging
 MANE-4490 Mechatronics
 MANE-4250 Mechatronic System Design

Minor Programs

Minors in any of the three ECSE curricula are open to undergraduates not majoring in any of these disciplines. The corresponding curriculum chair must approve all minors.

In Electrical Engineering, the minor consists of:

ECSE-2010 Electric Circuits 4
 ECSE-2410 Signals and Systems4
 ECSE-2610 Computer Components and
 Operations.....4
 Approved ECSE elective3-4

In Computer and Systems Engineering, the minor consists of:

ECSE-2010 Electric Circuits4
 ECSE-2610 Computer Components and
 Operations.....4
 ECSE-2660 Computer Architecture, Networks,
 and Operating Systems4
 Approved ECSE elective3-4

In Electric Power Engineering, the minor

consists of:

ECSE-2010 Electric Circuits4
 ECSE-2050 Analog Electronics *or*
 ENGR-4300 Electronic Instrumentation.....4
 ECSE-2100 Fields and Waves4
 EPOW-4020 Electromechanics.....4
 EPOW-4010 Power Engineering Fundamentals *or*
 EPOW-4080 Semiconductor Power Electronics.....4

Dual Major Programs

These programs lead to a single baccalaureate degree embracing two fields. Special programs that can be completed in eight terms have been devised for:

- Electrical engineering and applied physics
- Electrical engineering and computer and systems engineering
- Electrical engineering and electric power engineering
- Computer and systems engineering and computer science

See the ECSE web page for detailed information about these programs.

Professional Programs

ECSE students following the Electric Power Engineering Program may follow this option to complete both the B.S. and M.S. degrees. In this case, the fourth year follows closely the outline for the last year of the baccalaureate program. However, in choosing electives the student should bear in mind that the following courses must be taken at some time prior to or during the professional program:

- ENGR-4760 Engineering Economics
- Mathematics elective at 4000 level or higher

The following 4000-level courses (or their equivalents) can be used to satisfy the degree’s mathematics course requirement:

- MATH-4600 Advanced Calculus
- MATH-4300 Intro. to Complex Variables: Theory and Applications
- MATH-4500 Methods of Partial Differential Equations of Mathematical Physics
- MATH-4700 Foundations of Applied Mathematics

The typical curricula for the remainder of the program is as follows:

Fifth Year

Fall		Credit hours	Spring		Credit hours
EPOW-6810	Power Engineering Analysis	3	EPOW-6870	Mechanical Aspects of Electric Power Apparatus	3
EPOW-6850	Electric and Magnetic Fields in Electric Power Eng.	3	EPOW-6890	Computer Methods in Electric Power Engineering	3
	Selected Power Courses ¹	3		Selected Power Courses ¹	3
	Electives	6		Electives	6

A student wishing to qualify for a B.S. degree by the end of the first year of professional school studies must complete the humanities and social sciences core requirement during the first year of the professional program.

Special Undergraduate Opportunities

ECSE offers a couple of special programs for highly qualified students. These include:

The Undergraduate Honors program

This program for outstanding undergraduates in electrical engineering or computer and systems engineering introduces research as a professional activity. All participants attend the ECSE Honors Seminar during their sophomore or junior year. Students also participate in at least one research project. An honors faculty adviser is assigned with whom special academic programs are developed that reflect the capabilities and interests of the exceptional student. Applications are accepted during a student’s third semester or thereafter. Forms are available from the department curriculum office.

¹ At least two courses should be selected from the following:

EPOW-6820	Power Quality (Spring)	EPOW-6960	Topics in Electric Power Engineering (Spring or Summer)
EPOW-6880	Utility as a Business (Spring or Summer)	EPOW-6860	Surge Phenomena in Electric Power Engineering (Fall)
EPOW-6830	Protective Relaying (Fall; offered on availability of instructor)	ENVE-4400	Nuclear Power Systems Engineering (Spring)
EPOW-6840	Power Generation Operation and Control (Spring)		

The Grainger Scholar program

This program is for well-qualified U.S. students in electric power engineering. Through this program, the power industry, under the auspices of the Grainger Foundation, supports study at Rensselaer.

Graduate Programs

The department offers graduate programs leading to the Master of Engineering, Master of Science, Doctor of Philosophy, and Doctor of Engineering in all three of the department curricula. In all cases, particular emphasis is placed on developing a coherent individualized Plan of Study with the help of a faculty adviser.

Master's Programs

Both the M.S. and the M.Eng. require 30 credits beyond the bachelor's degree.

Master of Science

This program is designed to prepare students for research-oriented careers and eventual pursuit of a doctoral degree. A six-credit thesis or project is usually required, but it may be waived for students who can submit a document of previous individual work that demonstrates equivalency in depth and presentation. Waivers are granted by the director of master's programs and must be replaced with six credit hours of course work.

The M.S. Plans of Study in electrical engineering and computer and systems engineering must consist of at least 18 credit hours of 6000-level courses and the thesis/project. At least 21 credit hours of ECSE courses must be taken, or up to six of these may be from a related technical area with the approval of the department. Programs that do not include 21 credit hours from ECSE must have prior approval from the director of master's programs. Students who do not have adequate preparation for their chosen area of specialization may need to take background courses in addition to the 30-credit-hour requirement. An information sheet giving the requirements for several areas of specialization is available for all accepted students.

In the electric power engineering curricula, most study and research is of an applied nature, which is recognized in the awarding of the M.Eng. degree. However, courses and research directed more toward basic understanding of physical phenomena, such as the fundamental processes of electrical breakdown in dielectrics, can be pursued. This type of research would lead to the M.S. degree. This avenue also allows students with accredited degrees—not in engineering but perhaps in science—to obtain advanced degrees in the electric power area.

Master of Engineering

This one-year program is designed to prepare graduates for professional careers. Students entering the program typically hold accredited bachelor's degrees in appropriate branches of engineering. A master's thesis or project is not required.

The M.Eng. Plans of Study in electrical engineering and computer and systems engineering consist of at least 18 credit hours in 6000-level courses. In addition, it must include at least 21 credit hours in ECSE courses, or up to six of these may be from a related technical area with the approval of the department. Programs that do not include 21 credit hours from ECSE must have prior approval from the director of master's programs. Students who do not have adequate preparation for their chosen area of specialization may need to take background courses in addition to the 30-credit-hour requirement. An information sheet giving the requirements for several areas of specialization is available for all accepted students.

The electric power engineering M.Eng. degree is a structured program of advanced professional study for the student holding an accredited bachelor's degree in the field or its equivalent in electrical engineering.

Course listings do not represent requirements except where indicated (see the fifth year requirements listed earlier); they are intended only to guide the student, who is encouraged to develop an individual program in consultation with his or her graduate adviser.

Doctoral Programs

Advanced study and research for a Ph.D. or D.Eng. degree is conducted under the guidance of a thesis adviser representing the department. The student formulates an individual Plan of Study in consultation with the adviser. The doctoral qualifying examination should be taken prior to completing 15 credit hours beyond the master's degree. A minimum of 60 credit hours beyond the master's degree, including a dissertation, is required. The department expects the Institute requirements for candidacy and residency to be satisfied.

In the electric power engineering curricula, most study and research is of an applied nature, which is recognized in the awarding of the D.Eng. degree. However, courses and research directed more toward basic understanding of physical phenomena, such as the fundamental processes of electrical breakdown in dielectrics, can be pursued. This type of research would lead to the Ph.D. degree. This avenue also allows students with accredited degrees—not in engineering but perhaps in science—to obtain advanced degrees in the electric power area.

Special Graduate Opportunities

In collaboration with the various campus centers and other departments, ECSE sponsors master's and doctoral program options in manufacturing systems and semiconductor technology. Descriptions of these programs are available upon request.

Course Descriptions

Courses directly related to all Electrical, Computer, and Systems Engineering curricula are described in the Course Description section of this catalog under the department codes CSCI, DSES, ECSE, ENVE, EPOW, ITEC, MATH, MATP, MTLE, and PHYS.

Materials Science and Engineering

Department Head: David J. Duquette

Undergraduate Advising: Pawel Koblinski

Graduate Recruiting: Roger N. Wright

Graduate Advising: Christoph Steinbruchel

Department Home Page: <http://www.eng.rpi.edu/dept/materials/>

Progress in modern technology is often limited by the availability of suitable solid materials. The materials engineer must produce materials to meet the demands of the designers of jet engines and rocket boosters, microelectronic devices, optical components, medical prostheses, and many other products.

The principles that govern the processing and structure of materials to produce optimum mechanical and physical properties and performance are embodied in the materials engineering curriculum. The program is designed to produce engineers and scientists whose degrees represent useful specialization coupled with a broad background in all classes of materials.

Undergraduate students wishing to extend their education can undertake specialized study in a range of

fields. These include research in ceramics, polymers, composites, nanostructured materials, high-temperature alloys, solidification, corrosion, deformation processing, welding, high-strength high-modulus materials, biomaterials, electronic materials, surface and molecular kinetics, glass science, and the origin of mechanical and physical properties in many different types of materials. Graduate students, in addition to pursuing classroom courses, conduct research in a variety of areas described below and write their theses based on this research. Extensive laboratories containing modern and sophisticated equipment are available.

For the student who likes to innovate and who wants to apply knowledge to the real problems of a modern technological society, materials science and engineering provides a broad range of exciting opportunities.

Research and Innovation Initiatives

Materials Processing

Major research programs include fundamental studies of the solidification process and the effect of solidification under reduced gravity on the formation of dendritic structures, and practically oriented programs in the extrusion processing of aluminum alloys. In the latter program, studies of the complex interactions among stress, strain rate, and temperature during forming processes have made it possible to apply advanced software models to the control of metalworking operations. Studies of powder processing have made possible the extrusion processing of composite materials, while research on joining processes has led to synergistic coupling of adhesive bonding and spot welding technology in automotive sheet metal fabrication. New efforts focused on the synthesis, processing, and properties of nanostructured materials are expanding the capabilities of materials engineering and nanotechnology into additional areas including ceramics, metals, polymers, composites, and biomaterials. Novel applications of carbon nanotubes for device and chemical applications are under investigation, along with chemical, electrical, and mechanical isolation engineering using nanocomposites.

Materials for Microelectronic Systems

This research concentrates on materials problems associated with the interconnections between integrated circuit elements. Included are the growth of thin films of metals and both polymer and ceramic dielectric materials, the patterning and etching processes necessary for the fabrication of multilayer devices, and the planarization processes necessary for successful device fabrication.

Glasses and Ceramics

Research efforts focus on factors influencing the useful lifetime of glass components and the effect of environments, especially aqueous environments, on glass failure. In addition to the conventional applications such as windows and bottles, glasses are used as optical components such as optical communication fibers. Specifically, variation of the glass surface structure with time and its influence on glass properties are under investigation. Another emphasis is the development of nonoxide glasses, primarily those based on fluorides, as the transmitting medium in optical fibers for communications purposes.

High-Performance Composite Materials

These materials are used in industrial and consumer products due to their exceptional stiffness and strength-to-weight ratios. Applications of composites in the construction industry, such as steel bridge repairs using graphite-epoxy composites, are growing rapidly. Meanwhile, next generation conceptual plans for hybrid electric vehicles are using ceramic composite components for gas turbine engines and thermal recuperators. Composites research activities at Rensselaer include ceramic, metallic, and

polymer matrix composites; micromechanics and modeling of both fabrication processes and materials properties; design with new materials; synthesis of new matrix materials; and all aspects of the fabrication and characterization of composites and composite structures. Of special note is the sailplane program, in which students have designed, fabricated, and tested an all-composite glider, which has now been flying for over seven years. A new project, the composite hybrid electric vehicle, has also been initiated and offers numerous opportunities for both graduate and undergraduate participation.

Faculty*

Professors

- Ajayan, P.M.**—Ph.D. (Northwestern University); synthesis, structure, and properties of carbon-based nanostructures and nanocomposites; phase transitions in nanoscale materials; electron microscopy.
- Chrisey, D.B.**—Ph.D. (University of Virginia); novel laser microfabrication, mesoscopic conformal electronics, thin film batteries, laser shock processing, magnetically controlled biological sensors, nanoparticles at high pressure
- Cramb, A.W.**—Ph.D. (University of Pennsylvania); liquid steel processing, continuous casting of steel; clean steel production, initial solidification phenomena during continuous casting and the behaviour of liquid oxides
- Duquette, D.J.**—Ph.D. (Massachusetts Institute of Technology); environmental and surface effects on the mechanical behavior of metals, corrosion, stress corrosion fatigue (Department Head).
- Glicksman, M.E.**—Ph.D. (Rensselaer Polytechnic Institute); melting and solidification, transport properties of liquid metals, phase transformation kinetics, metallurgy of superconductors (John Tod Horton Professor of Materials Engineering).
- Messler, R.W., Jr.**—Ph.D. (Rensselaer Polytechnic Institute); materials in manufacturing, welding.
- Nalamasu, O.**—Ph.D. (University of British Columbia); electronic and photonic polymers, nanopatterning, micro- and nanofabrication, electronic and photonic devices.
- Schadler, L.S.**—Ph.D. (University of Pennsylvania); polymer and glass matrix composites, micromechanical behavior, strains and interface properties, micro-Raman spectroscopy, environmental effects.
- Siegel, R.W.**—Ph.D. (University of Illinois); synthesis, processing, structure, and properties of functional nanostructured materials including metals, ceramics, and composites; biomaterials; atomic-scale defects and diffusion in materials (Robert W. Hunt Professor).
- Sternstein, S.S.**—Ph.D. (Rensselaer Polytechnic Institute); high-performance composites; physical properties of polymers; rubber elasticity theory; fracture, yielding, and craze formation in glassy polymers and composites, viscoelastic properties; swelling in filled elastomers (William Weightman Walker Professor of Polymer Engineering).
- Tomozawa, M.**—Ph.D. (University of Pennsylvania); electrical properties of glasses, X-ray and light scattering, phase separation, mechanical properties of glasses.
- Wright, R.N.**—Sc.D. (Massachusetts Institute of Technology); metal forming and fabrication, mechanical behavior of metals.

Associate Professors

- Keblinski, P.**—Ph.D. (Pennsylvania State University); atomic mesoscopic-level computational modeling of interfacial processes; structure-property correlations; interfaces in silicon, diamond and metals; thin film growth; phase separation.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting.

Ramanath, G.—Ph.D. (University of Illinois); thin film electronic materials; interconnects, diffusion barriers, low-k dielectrics; characterization of interfacial reactions, kinetics, and mechanisms of microstructure and phase evolution during deposition and annealing; processing self-organized structures for microelectronics applications.

Steinbruchel, C.—Ph.D. (University of Minnesota); thin films, electronic materials, plasma processing, ion beam and ultra-high vacuum techniques.

Assistant Professors

Gall, D.—Ph.D. (University of Illinois, Urbana-Champaign); physical properties of thin films and nanostructures; combined theory, modeling and experimentation in thin film technology as applied to electronic structures and properties, transition-metal nitride film growth and characterization.

Lewis, D.J.—Ph.D. (Lehigh University); solidification and diffusion in multicomponent solids, modeling of phase transformations.

Ozisk, R.—Ph.D. (The University of Akron, Ohio); multiscale simulations of polymers, surface and interface properties of nanoparticles; development and characterization of fuel cells.

Shima, M.—Ph.D. (University of Maryland); thin film deposition; nano-patterning, structural and magnetic characterization.

Research Professors

Eisman, G.—Ph.D. (Northeastern University); fuel cells, ceramic powder synthesis, electrochemical engineering, chloralkali technology.

Emeritus Faculty

Chung, C.I.—Ph.D. (Rutgers University); polymer processing, polymer melt rheology, relaxation behavior in polymer solids.

Doremus, R.H.—Ph.D. (University of Cambridge), Ph.D. (University of Illinois); glass science, sintering of ceramics, bone implant materials, reactions in fused salts, crystallization, diffusion, optical properties of metals (New York State Science and Technology Foundation Professor of Glass and Ceramics Science).

Ficalora, P.J.—Ph.D. (Pennsylvania State University); kinetics and thermodynamics of heterogeneous reactions, chemisorption effects on electronic materials.

Hudson, J.B.—Ph.D. (Rensselaer Polytechnic Institute); adsorption on solid surfaces, structure and reactivity of solids, physics and chemistry of surfaces, nanocrystal growth.

MacCrone, R.J.—D.Phil. (University of Oxford); electric properties of polymers and oxides, polarons, electron paramagnetic resonance and magnetic behavior of glasses, phase transformations, nucleation, electrical properties of thin oxide and nitride films, one-dimensional conductivity.

Moynihan, C.T.—Ph.D. (Princeton University); ionic transport in glass, infrared transmission in glasses and glass ceramics, thermodynamic properties of glasses.

Murarka, S.P.—Ph.D. (University of Minnesota); Ph.D. (University of Agra); metallization for deep submicron silicon integrated circuits, low temperature and localized processes, thin dielectric films, diffusion and defects (Elaine S. and Jack S. Parker Chair in Engineering).

Stoloff, N.S.—Ph.D. (Columbia University); mechanical behavior of crystals, order-disorder reactions, fracture, stress corrosion.

Manager of Electron Microscopy Facilities

Dove, R.

Manager of Instruction Laboratories

Van Steele, D.

Manager of Metallographic Facilities

Planty, R.

Undergraduate Programs

Objectives of the Undergraduate Curriculum

While certain objectives of an undergraduate education in engineering are common to all programs, there are subtle but important differences that require some subset of objectives specific to ensuring that all graduates have specialized technical knowledge in their chosen field. In this regard, the Department of Materials Science and Engineering's baccalaureate program produces students who will:

- Exhibit general knowledge in all major classes of materials and specialized knowledge in several classes, such as metals, ceramics and glasses, polymers, composites and electronic materials.
- Recognize the interdependence of the structure, properties, processing, and performance of materials and be able to integrate fundamental materials science with analysis of experimental data, laboratory synthesis and processing as well as quantitative modeling.
- Integrate meaningful design experiences within Materials Engineering and in relationship to other engineering disciplines.
- Exhibit a thorough grounding in fundamental mathematics and science and the ability to apply this knowledge in identifying, formulating, and solving real-life engineering problems.
- Be able to put engineering problems, their solutions, and consequences into a societal context.
- Effectively communicate and work in teams.
- Maintain a desire for life-long learning.

Baccalaureate Program

The sample curriculum shown below, which results in the B.S. degree in Materials Engineering, requires a minimum of 128 credit hours and completion of the required elective courses that follow.

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis	4	ENGR-1300	Eng. Processes.....	1
MATH-1010	Calculus I	4	ENGR-1600	Materials Science for Engineers	4
CHEM-1100	Chemistry I.....	4	MATH-1020	Calculus II	4
	Hum. or Soc. Sci. Elective	4	PHYS-1100	Physics I	4
				Hum or Soc. Sci. Elective	4

Second Year

Fall		Credit hours	Spring		Credit hours
PHYS-1200	Physics II.....	4		Science Elective ¹	4
MATH-2400	Intro. to Differential Equations	4	MTLE-2100	Structure of Materials	4
ENGR-2250	Therm./Fluid I	4	ENGR-2050	Intro. to Engineering Design.....	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4
ENGR-1200	Engineering Graphics and CAD	1	CSCI-1190	Beginning C Programming for Engineers	1

Third Year

Fall		Credit hours	Spring		Credit hours
ENGR-2600	Modeling & Anal. of Uncert.	3	MTLE-4250	Prop. of Eng. Materials II	4
MTLE-4200	Prop. of Eng. Materials I	4	MTLE-4150	Kinetics of Materials	4
MTLE-4100	Thermo. of Materials	4		Restricted Elective	4
	Professional Dev. II ²	2		Free Elective I	4
	Hum. or Soc. Sci. Elective	4			

¹ Students are encouraged to select a life science course, such as BIOL-1010.

² This course will be fulfilled from a list published at the start of each semester.

Fourth Year

Fall		Credit hours	Spring		Credit hours
ENGR-4010	Professional Development III ³	1	MTLE-4920	Appl. of Materials	2
MTLE-4910	Design in Materials Eng.	3	MTLE-4450	Materials Syn. and Proc. II	4
MTLE-4400	Materials Syn. and Proc. I	4		Materials Elective II	3
	Materials Elective I	3		Free Elective III	4
	Free Elective II.....	4			

Electives

The following is a list of courses from which the electives indicated above should be selected.

Restricted Elective Options

ENGR-2530	Strength of Materials
ENGR-2350	Embedded Control
ENGR-2090	Engineering Dynamics
ECSE-2010	Electric Circuits
ENGR-4300	Electronics Instrumentation

Materials Electives

MTLE-4030	Glass Science
MTLE-4050	Intro. to Polymers
MTLE-4160	Semiconducting Materials
MTLE-4310	Corrosion
MTLE-4410	Welding Processes and Metallurgy
MTLE-4420	Joining of Advanced Materials

Minor Programs

Students not majoring in materials science and engineering may receive a minor in this discipline by completing 15 credit hours of department courses with a MTLE designation.

Graduate Programs

The Department of Materials Science and Engineering offers programs leading to the M.S., M.Eng., and Ph.D. degrees.

Master's Programs

Both the M.S. and the M.Eng. require completion of a minimum of 30 credit hours.

Master of Science

For the M.S., students must complete 24 credits of course work, with at least 18 credits in materials courses. Three credits each are required in the areas of thermodynamics and kinetics, structure, and mechanical properties. Students who have not taken courses equivalent to undergraduate work at Rensselaer in X-ray diffraction, thermodynamics, mechanical properties, and their area of specialization must take graduate courses in these areas. Six credits of research work leading to an M.S. thesis are also required.

Master of Engineering

At least 21 credits of course work toward the M.Eng. degree must be materials courses. These must include one course each in structure and defects, thermodynamics and kinetics, and mechanical properties. A capstone independent study project is also required.

Doctoral Programs

A minimum of 45 credits in course work is required for the Ph.D. degree in materials engineering. In addition to the course requirements for the M.S. degree, a minor of nine credits in a subject area outside the materials department is required. The student must pass an oral preliminary examination and an oral candidacy examination, as well as the final examination on the Ph.D. thesis.

³ This course can be taken in either semester of senior year.

Course Descriptions

Courses offered by the Department of Materials Science and Engineering are described in the Course Description section of this catalog under the department code MTLE.

Mechanical, Aerospace, and Nuclear Engineering

Department Head: Timothy Wei

Director, Mechanical Engineering and Aerospace Engineering Programs: Timothy Wei

Director, Nuclear Engineering and Engineering Physics Program: Don Steiner

Associate Head for Graduate Studies: Antoinette Maniatty

Associate Head for Undergraduate Studies: Henrik J. Hagerup

Department Home Page: www.rpi.edu/dept/mane

Mechanical engineers are engaged in a wide range of activities. At one end of the spectrum, they are concerned with fundamental engineering science, especially energetics and mechanics. At the other end, they are involved with the hardware of various technologies—the design and manufacture of mechanical components and systems. Aerospace engineering is concerned with disciplines and technologies that pertain not only to aircraft and spacecraft, but to other vehicular systems such as submarines and hydrofoils as well. Nuclear engineering and engineering physics focus on the methods, devices, and systems required for the peaceful use of nuclear technology. While nuclear engineering's emphasis is on nuclear power generation, engineering physics emphasizes the radiation aspect of this technological area.

Research and Innovation Initiatives

Opportunities for research and innovation are delineated below. Opportunities may be theoretical, computational, and/or experimental. The Flexible Manufacturing Center, the Center for Multiphase Research, the New York State Center for Automation Technologies, the Scientific Computation Research Center, and the Center for Integrated Electronics offer additional research opportunities for the department's undergraduate and graduate students and their faculty advisers.

Aeronautics

Research is conducted into the performance of fixed wing aircraft, rotorcraft, and space vehicles, as well as micro-vehicles. The research is supported by fundamental studies in aerodynamics, advanced propulsion concepts, vehicle dynamics, and design optimization. Facilities include the fluid dynamics laboratory and the structures and controls laboratory.

Applied Mechanics/Mechanics of Materials

Applied Mechanics refers to the theoretical foundations of mechanical engineering. Basic research is being performed on diverse topics such as acoustics, fatigue and fracture processes, nonlinear vibrations, and plasticity. Materials of the latest technologies such as composites, microelectronic materials, and carbon nanotubes are studied from the mechanical perspective. The finite element method is a computational approach in modeling material behavior.

Facilities include the mechanics of materials laboratory, the laboratory for noise control research, and the mechanical systems laboratory.

Energy Systems/Multiphase Phenomena and Heat Transfer

Studies are related to energy conversion and the development of mechanical power, convective heat transfer and freezing, electronic cooling, fouling, heat transfer augmentation, mass transfer, computational fluid dynamics and multidimensional effects in multiphase flow, and heat transfer with applications in nuclear, mechanical, thermal, chemical, biomedical and pharmaceutical systems, development of mechanistic models, and computer simulation capabilities.

Mechanical and Nuclear Engineering are both concerned with energy conversion and the development of mechanical power. Issues of heat transfer are important, from a range of large-scale industrial processes, down to the cooling of electronic micro components with extreme power density. Thermal and fluid flow properties are studied by theoretical and computational means (computational fluid dynamics). Multiphase processes are important in problems from drug delivery optimization to nuclear power cooling systems.

Facilities include the gas turbine laboratory; the energy systems laboratory; subsonic, and supersonic wind tunnels; shock tubes and the hypersonic shock tunnel; the heat transfer laboratory; and the laboratory for fouling research. Additional equipment includes various two-phase flow loops and associated instrumentation, laser Doppler anemometer, optical void probes, and the resources of the Center for Multiphase Research.

Environmental Health Physics and Radiation Dosimetry

Research in this area has diverse applications: the assessment of environmental radioactivity for the nuclear industry; investigations of health physics practices in hospitals; analysis of worker effective doses from external and internal exposures; and optimization of radiation therapy doses in biomedical applications. These problems are studied theoretically by Monte Carlo methods, among several techniques. Facilities include a versatile health physics laboratory and modern nuclear radiation detection and characterization systems.

Manufacturing/Design

Studies revolve around design methodology in general and mechanical engineering design techniques in particular. There are applications in machinery and mechanical systems design, the development of new manufacturing techniques, and operation of manufacturing facilities. Areas of concentration include CAD/CAM, diagnostics and controls, tribology, metrology rapid prototyping, robotics and flexible manufacturing, and system integration. Facilities include the advanced manufacturing laboratory, the design optimization laboratory, the robotics and mechanisms laboratory, and the mechatronics laboratory.

Nuclear Science and Technology

Research involves a wide spectrum of issues crucial to the nuclear industries. Investigations are ongoing into the interaction of neutrons and other radiation with materials used in nuclear reactors; nuclear data analysis and evaluation; radiation transport studies; conceptual designs of fusion power systems and their engineering, safety, and environmental implications; plasma wall interactions; analysis of reactor accidents and safety studies. Facilities include a versatile 100-Mev electron linear accelerator, time-of-flight and associated instrumentation, a critical reactor facility, a three-dimensional laser Doppler anemometer, and miscellaneous nuclear radiation equipment and computational aids.

Space Technology

Research areas include analysis, design, development, and operations required for space exploration and utilization. Research is ongoing in advanced energetics (laser propulsion), structural dynamics and optimization, and crystal growth in space. Facilities include various supersonic wind tunnels, the shock tube, and crystal growth laboratories.

Faculty*

Professors

- Blanchet, T.A.**—Ph.D. (Dartmouth College); tribology, solid lubrication, surface science, contact mechanics.
- Craig, K.C.**—Ph.D. (Columbia University); design, tribology, mechanics, controls (Chair, Engineering Science, and Director, Core Engineering).
- Drew, D.A.**—Ph.D. (Rensselaer Polytechnic Institute); applied mathematics, fluid mechanics (joint appointment, Mathematics home department).
- Dvorak, G.J.**—NAE, Ph.D. (Brown University); mechanics of solids, composite materials and structures, fracture and fatigue (William Howard Hart Professor of Mechanics).
- Fish, J.**—Ph.D. (Northwestern University); computational mechanics, finite element methods, micromechanics, mathematical modeling (jointly with Civil Engineering; Rosalind and John J. Redfern Jr. '33 Professor of Engineering).
- Hirsa, A.**—Ph.D. (University of Michigan); fluid mechanics, experimental gas dynamics (jointly with the Chemical and Biological Engineering Department).
- Gabriele, G.A.**—Ph.D. (Purdue University); design automation, design optimization.
- Hajela, P.**—Ph.D. (Stanford University); optimum design, structural dynamics, aeroelasticity (Vice Provost for Administration, Dean of Undergraduate Education).
- Jensen, M.K.**—Ph.D., P.E. (Iowa State University); heat transfer, fluid mechanics, energy systems.
- Lahey, R.T., Jr.**—NAE, Ph.D., (Stanford University); multiphase flow and boiling heat transfer, reactor safety analysis, reactor thermal-hydraulics, applications of chaos theory (jointly with the Chemical Engineering Department; Edward W. Hood Jr. Professor).
- Li, C.J.**—Ph.D. (University of Wisconsin-Madison); control of manufacturing process and equipment, machine condition monitoring, nonlinear system identification.
- Malaviya, B.K.**—Ph.D. (Harvard University); fission and fusion reactor physics and technology, biomedical applications, radioactive waste management, pedagogic technology (jointly with Engineering Science).
- Maniatty, A.M.**—Ph.D. (Cornell University); continuum mechanics, mechanics of materials.
- Messac, A.**—Ph.D. (Massachusetts Institute of Technology); optimal design, physical programming, design methodology, structural dynamics.
- Ostrogorsky, A.G.**—Sc.D. (Massachusetts Institute of Technology); heat transfer and fluid mechanics, solidification, crystal growth (jointly with Materials Science and Engineering Department).
- Peterson, G.P. “Bud”**—Ph.D. (Texas A&M University); two phase heat transfer (Provost).
- Podowski, M.Z.**—Ph.D. (Warsaw University of Technology); two-phase flow and heat transfer, reactor dynamics and safety, system stability, applied mathematics.
- Rusak, Z.**—D.Sc. (Technion-Israel Institute of Technology); theoretical aerodynamics, fluid mechanics.
- Smith, R.N.**—Ph.D. (University of California, Berkeley); energy systems (Associate Dean, Academic and Students Affairs).
- Shephard, M.S.**—Ph.D.(Cornell University); finite element analysis, computer graphics, computer-aided design (jointly with the Civil Engineering Department; Samuel A. Johnson'37 and Elizabeth C. Johnson Professor of Engineering).
- Spilker, R.L.**—Ph.D. (Massachusetts Institute of Technology); biomechanics, finite element methods (joint appointment, Biomedical Engineering home department).
- Tichy, J.A.**—Ph.D. (University of Michigan); tribology, non-Newtonian fluid mechanics, rheology.

* Departmental faculty listings are accurate as of the date generated for inclusion in this catalog. For the most up-to-date listing of faculty positions, including end-of-year promotions, please refer to the Faculty Roster section of this catalog, which is current as of the May 2006 Board of Trustees meeting

Tiersten, H.F.—Ph.D., P.E. (Columbia University); continuum mechanics, continuum physics, electro-mechanical devices, structures.

Wei, T.—Ph.D. (University of Michigan); turbulence, fluid-structure interactions, biological flows, (Department Head).

Wen, J.T.—Ph.D. (Rensselaer Polytechnic Institute); nonlinear control, robot control, flexible structures control, deformation processes control (joint appointment, Electrical, Computer, and Systems Engineering home department).

Associate Professors

Anderson, K.S.—Ph.D. (Stanford University); multibody dynamics, parallel computing, vehicle dynamics.

Castillo, L.—Ph.D. (State University of New York at Buffalo); fluid mechanics, turbulent boundary layers.

Danon, Y.—Ph.D. (Rensselaer Polytechnic Institute); nuclear instrumentation and data, accelerator technology and radiation applications, nondestructive testing, neural networks applications.

Derby, S.J.—Ph.D. (Rensselaer Polytechnic Institute); automation, mechanisms, robotics, design.

Embrechts, M.J.—Ph.D. (Virginia Polytechnic Institute); fusion engineering, applied chaos theory, neural networks (joint appointment, Decision Sciences and Engineering Systems home department).

Hagerup, H.J.—Ph.D. (Princeton University); viscous flow.

Huang, H.—Ph.D. (University of California, Los Angeles); nanomechanics of materials, thin film deposition, radiation damage, multiscale materials modeling.

Jansen, K.—Ph.D. (Stanford University); computational mechanics, parallel computing, computational fluid dynamics.

Kaminski, D.A.—Ph.D. (Rensselaer Polytechnic Institute); heat transfer, computational fluid mechanics, thermal radiation.

Koratkar, N.A.—Ph.D. (University of Maryland at College Park); smart materials and structures, rotorcraft, unsteady aerodynamics.

Myrabo, L.N.—Ph.D. (University of California, San Diego); energy systems, space technology.

Picu, C.R.—Ph.D. (Dartmouth College); mechanics of solids, micro- and nano-mechanics of crystalline defects, atomistic simulations.

Scarton, H.A.—Ph.D. (Carnegie Mellon University); biomechanics, wave phenomena, acoustics, noise control.

Walczyk, D.E.—Ph.D., P.E. (Massachusetts Institute of Technology); rapid tooling, environmentally conscious design, machine design.

Xu, G.X.—Ph.D. (Texas A&M University); environmental health physics, health and medical physics, Monte Carlo simulations, anatomical modeling, biomedical use of radiation (jointly with the Biomedical Engineering Department).

Clinical Associate Professor

Alben, R.—Ph.D. (Harvard University); electronic materials, engineering education, engineering management, entrepreneurship, manufacturing and service operations.

Steiner, M.W.—Ph.D. (Rensselaer Polytechnic Institute); multidisciplinary design, product architecture, advanced design methods.

Assistant Professors

Amitay, M.—D.Sc. (Technion-Israel Institute of Technology); aerodynamics flow control, mini- and micro-unmanned aerial vehicles and two-phase flows with applications in medical engineering.

Borca-Tasciuc, D.—Ph.D. (University of California, Los Angeles); MEMS, NEMS, microfluidics, heat transfer in nanosystems.

Borca-Tasciuc, T.—Ph.D. (University of California, Los Angeles); heat transfer and energy conversion, nanotechnology, MEMS.

De, S.—Sc.D. (Massachusetts Institute of Technology); numerical methods in engineering, multimodal virtual environments, fast computational techniques of MEMS.

Oberai, A.—Ph.D. (Stanford University); multiscale modeling, turbulence modeling and simulation, computational biomechanics, inverse problems.

Oehlschlaeger, M.—Ph.D. (Stanford University); combustion, propulsion and energy systems, optical diagnostics.

Peles, Y.—Ph.D. (Technion-Israel Institute of Technology); MEMS fabrication, design and device testing, design and manufacturing of electronic packaging.

Research Professors

Steiner, D.—Ph.D. (Massachusetts Institute of Technology); nuclear fusion systems, plasma engineering, radiation effects on materials (Institute Professor of Nuclear Engineering).

Research Assistant Professors

Antal, S.—Ph.D. (Rensselaer Polytechnic Institute); computational fluid dynamics, numerical methods in multiphase flows, heat transfer.

Senior Lecturer

Swersey, B.L.—B.S. (Cornell University); creativity in design, design methodology.

Adjunct Faculty

Anderson, T.—Ph.D. (New York University); plasma physics, fluid dynamics, reactor physics and radwaste management, environmental engineering.

Borton, D.N.—Ph.D. (Rensselaer Polytechnic Institute); solar energy.

Caracappa, P.—M.S. (Rensselaer Polytechnic Institute); radiation safety, health physics.

DeLorey, T.F.—Ph.D. (Massachusetts Institute of Technology); reactor physics, computational physics, software engineering.

Francis, N.—Ph.D. (University of Rochester); reactor physics.

Haley, T.—Ph.D. (Rensselaer Polytechnic Institute); nuclear fuel management, mathematical modeling, reactor design.

Trumbull, T.H.—M.Eng. (Rensselaer Polytechnic Institute); research reactor experimental operations.

Witter, J.K.—Ph.D. (Massachusetts Institute of Technology); reactor physics, plant operations, thermal hydraulics, reactor for space applications.

Emeritus Faculty

Bergles, A.E.—PE., NAE, Ph.D. (Massachusetts Institute of Technology); heat transfer, two-phase flow.

Block, R.C.—Ph.D. (Duke University); nuclear structure and data, radiation effects in electronics, accelerator technology neutron reactions, real-time radiography, industrial applications of radiation, nondestructive testing.

Crespo da Silva, M.R.M.—Ph.D. (Stanford University); dynamics, nonlinear vibrations, perturbation methods, computerized symbolic manipulation.

Ettles, C.M.—Ph.D. (Imperial College), D.Sc. (University of London); mechanical design, machine dynamics, tribology.

Harris, D.R.—Ph.D. (Rensselaer Polytechnic Institute); reactor physics, fusion technology, shielding, reactor noise analysis.

Krempf, E.—Dr.Eng. (Technical University of Munich); continuum mechanics; mechanics of materials; creep, fatigue, inelastic analysis (Rosalind and John J. Redfern Jr. Professor of Engineering).

Lee, D.—Sc.D. (Massachusetts Institute of Technology); mechanics of materials, computer-aided manufacturing.

Nagamatsu, H.T.—Ph.D. (California Institute of Technology); hypersonics, transonics, plasma dynamics, aeroacoustics, heat transfer.

Sneck, H.J., Jr.—Ph.D., P.E. (Rensselaer Polytechnic Institute); viscous-fluid mechanics, bearing lubrication and design.

Somerscales, E.F.C.—Ph.D. (Cornell University); heat transfer.

Technical Support Staff

Brand, P.

Caracappa, P.

Gray, M.

McDougall, R.

Mielke, W.R., Jr.

Prince, L.

Trumbull, T.

Westhead, J.

White, E.

Undergraduate Programs

Objectives of the Undergraduate Curriculum

While certain objectives of an undergraduate education in engineering are common to all programs, there are subtle but important differences that require some subset of objectives specific to ensuring that all graduates have specialized technical knowledge in their chosen field. In this regard, graduates of the Department of Mechanical, Aerospace, and Nuclear Engineering's baccalaureate program will:

- Be able to apply skills in science and mathematics to the practice of engineering.
- Through a broad education in the humanities and social sciences, be able to identify and treat problems of interest to society.
- Have the ability to analyze real-world problems and to design products and systems for their solution.
- Develop strong communication skills both oral and written.
- Exhibit teamwork skills and leadership ability, working both within specialized and multidisciplinary settings, and form an awareness and appreciation of ethical and societal implications and the impact of engineering solutions in a global context.
- Have a broad foundation in mechanical systems, thermal and fluids engineering, and electronics and controls; be able to apply their knowledge to the design of mechanical and thermal/fluids systems and devices; gain additional technical depth in one or more areas of concentration, such as aeronautics, applied energy systems, design optimization, dynamics, heat transfer and fluid mechanics, manufacturing, mechatronics, and mechanics of materials; and be familiar with basic laboratory techniques in mechanical and in thermal/fluids engineering ; or
- Have a broad foundation in aerodynamics, aircraft structures, propulsion, and flight mechanics; be able to design and conduct experiments; and be familiar with basic numerical methods for engineering problems and the use of high-level computer software ; or
- Develop and demonstrate the ability to apply relevant atomic and nuclear phenomena to nuclear and radiological systems and processes, conduct experimental investigations, and work on design projects so as to be prepared to work professionally in one or more of the nuclear or radiological fields of specialization identified by the nuclear engineering program ; or
- Have a broad foundation in the application of engineering to physical systems and additional depth in one or more areas of concentration such as multiphase science, radiation technology, micro electronics, and applied mathematics; conduct experimental and analytical investigations and design projects; and develop the ability to work professionally in one or more of the areas of specialization identified by the engineering physics program.
- Be motivated for continued intellectual growth and improvement in engineering skill beyond

graduation.

Students may achieve these objectives through completion of the B.S. degree in mechanical engineering, aerospace engineering, nuclear engineering, or engineering physics. A variety of options are available to those pursuing the B.S., depending upon the specific degree program. These options, which include concentrations, minors, and/or dual majors are delineated within the following individual descriptions of each baccalaureate curriculum.

Baccalaureate Programs

Freshmen or sophomores who have identified mechanical, aerospace, nuclear engineering, or engineering physics as their major may follow the baccalaureate program below in lieu of the general core engineering program presented earlier. The total number of credit hours required to complete any of these curricula is 128. Dual major programs which lead to a single baccalaureate degree embracing two fields are also available and are described in more detail below.

Mechanical Engineering Curriculum

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1300	Engineering Processes ^{1,2}	1
ENGR-1200	Eng. Graphics and CAD ¹	1	ENGR-1600	Materials Science for Engineers	4
CHEM-1100	Chemistry I.....	4	MATH-1020	Calculus II	4
MATH-1010	Calculus I.....	4	PHYS-1100	Physics I.....	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4

Second Year

Fall		Credit hours	Spring		Credit hours
ENGR-2530	Strength of Materials	4	ENGR-2050	Intro. to Engineering Design	4
MATH-2400	Intro. to Differential Equations	4	ENGR-2090	Engineering Dynamics	4
PHYS-1200	Physics II.....	4	ENGR-2250	Thermal and Fluids Engineering I.....	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4
			CSCI-1190	Beginning C Programming for Engineers	1

Third Year

Fall		Credit hours	Spring		Credit hours
ENGR-2600	Modeling and Analysis of Uncertainty	3	ENGR-2350	Embedded Control	4
ENGR-4300	Electronic Instrumentation	4	MANE-4050	Modeling and Control of Dynamic Systems ⁵	4
	Mechanical Engineering Core Module ³	6		Mechanical Engineering Core Module ³	6
	Hum. or Soc. Sci. Elective	4		Professional Development II ⁴	2

¹ These required courses may be taken in any order.

² Alternative: ENGR-1310

³ Choice of Mechanical Design Module and Thermal and Fluids Module. Both modules are required for graduation; each module may be taken in either semester. The Mechanical Design Module consists of MANE-4030 and MANE-4040, taken concurrently. The Thermal and Fluids Module consists of MANE-4010 and MANE-4020, taken concurrently. Other third year courses may be taken in either semester.

⁴ This course will be fulfilled from a list published at the start of each semester. It must be completed before MANE-4260.

⁵ Course may be taken either semester.

Fourth Year**Credit hours**

MANE-4260	Design of Mechanical Engineering Systems.....	3
ENGR-4010	Professional Development III ⁶	1
	Concentration Elective (Restricted)....	3
	Concentration Elective (Restricted)....	3
	Concentration Elective.....	3
	Concentration Elective.....	3
	Free Elective ⁷	4
	Free Elective	4
	Free Elective	4

Concentrations

The mechanical engineering curriculum offers the following six concentration options.

Aeronautics

The focus is on the analysis, design, development, and operation of flight vehicles, which is fundamental for students interested in aeronautical engineering. This concentration provides a strong engineering and scientific foundation in fluid mechanics, thermodynamics, structural dynamics, vehicular mechanics, and control systems analysis. Student projects in recent years have involved spin preventions in fighter aircraft, trailing vortex dissipation, and helicopter maneuverability.

Applied Mechanics

This concentration provides the opportunity for fundamental study in fluid mechanics and solid mechanics. The objective is to develop broad analytical abilities and encourage critical inquiry. Programs in this area usually continue through the master's level. Topics have included cellular heat convection, locally separated flow, and inelastic fatigue analysis and fracture. Biomechanics, especially the mechanics of musculoskeletal systems, is part of this concentration.

Design

The concern here is with design methodology in general and mechanical design techniques in particular, and is intended for mechanical engineering students interested in the design of machinery and mechanical systems. A student interested in the design of specialized mechanical equipment can develop a suitable program from courses in this and other mechanical engineering concentrations.

Energy Systems

This concentration is intended for those interested in energy conversion and the development of mechanical power. Students concerned with the design of equipment in this field should consider this concentration together with the design concentration. Those interested in the fundamentals should consider this concentration together with the applied mechanics concentration.

Manufacturing Concentration

This area is intended for the mechanical engineering student who is interested in manufacturing and is planning a career designing manufacturing equipment, developing new manufacturing techniques, or operating manufacturing facilities.

⁶ Can be taken either semester senior year.

⁷ Students are encouraged to select a life science course, such as BIOL-1010.

Space Technology

This is an inherently multidisciplinary area that is offered for students interested in the analysis, design, development, and operations required for space exploration and utilization. Current areas of particular emphasis include the space environment, propulsion, orbital and structural dynamics, structures and control.

Concentration Electives Criteria

Students wishing to obtain any one of these concentrations must adhere to strict concentration electives criteria as follows. The first two courses within the four-course concentration are highly restricted. The first of these should be selected from the courses listed below. These courses define the concentration areas available within mechanical engineering and are thus termed “concentration-defining” electives.

Applied Mechanics

MANE-4670 Mechanical Behavior of Materials I
MANE-4170 Machine Dynamics
MANE-4610 Vibrations

Aeronautics

MANE-4070 Aerodynamics I
MANE-4060 Aerospace Structural Analysis

Design

MANE-4280 Design Optimization
MANE-4180 Mechanisms

Energy Systems

MANE-4710 Advanced Heat Transfer
MANE-4720 Design and Analysis of Energy
Systems

MANE-4800 Boundary Layers and Heat Transfer

Manufacturing

MANE-4550 Analysis of Manufacturing Processes
ENGR-4710 Advanced Manufacturing Laboratory I

Mechatronics

MANE-4490 Mechatronics

The second of the restricted concentration elective courses may be chosen from either:

- A list of courses associated with the originally defined concentration area. Such courses will be termed “concentration-completing” electives. Through them, a student clearly identifies a concentration within the mechanical engineering major.
- The original short list of concentration-defining electives. Through these, a student obtains greater breadth within mechanical engineering.

Any student wishing to satisfy these restricted concentration elective requirements in another way may first consult with the adviser and then propose a plan to the associate chair in undergraduate studies for approval. Students are reminded to consult the catalog and the *Class Hour Schedule* for the availability of a particular course in any given semester.

The second two courses of the four-course concentration are to be selected from any upper-level (4000 or above) course in science, engineering, or mathematics. One of these may be an independent study course, such as a design project or an undergraduate research project. The second course should not normally be a project. However, the associate chair for undergraduate studies may grant approval for an exception based on a particularly valuable research experience.

Humanities or Social Sciences Electives

In this area, the electives are based on the Institute and School of Engineering requirements. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Dual Major Programs

Dual majors lead to a single baccalaureate degree embracing two fields. Special programs which can be completed in eight semesters have been developed. Examples include dual majors in Mechanical Engineering and Aerospace Engineering, Mechanical Engineering and Biomedical Engineering,

Mechanical Engineering and Nuclear Engineering, Mechanical Engineering and Product Design and Innovation (STS), and others. Further information is available in the departmental office.

Aerospace Engineering Curriculum

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	ENGR-1300	Engineering Processes ^{1,2}	1
ENGR-1200	Eng. Graphics and CAD ¹	1		Hum. or Soc. Sci. Elective	4
CHEM-1100	Chemistry I.....	4	MANE-2060	Fundamentals of Flight	4
	Hum. or Soc. Sci. Elective	4	MATH-1020	Calculus II	4
MATH-1010	Calculus I.....	4	PHYS-1100	Physics I.....	4

Second Year

Fall		Credit hours	Spring		Credit hours
ENGR-2530	Strength of Materials	4	ENGR-2050	Intro. to Engineering Design.....	4
	Hum. or Soc. Sci. Elective	4	ENGR-2090	Engineering Dynamics	4
MATH-2400	Intro. to Differential Equations	4	ENGR-2250	Thermal and Fluids Engineering I....	4
PHYS-1200	Physics II.....	4		Hum. or Soc. Sci. Elective	4
			CSCI-1190	Beginning C Programming for Engineers	1

Third Year

Fall		Credit hours	Spring		Credit hours
ENGR-2600	Modeling and Analysis of Uncertainty	3	MANE-4050	Modeling and Control of Dynamic Systems ⁴	4
MANE-4060	Aerospace Structural Analysis	3	MANE-4030	Elements of Mechanical Design	4
MANE-4070	Aerodynamics I.....	3	MANE-4900	Aeroelasticity and Structural Vibration	3
MATH-4800	Numerical Computing	4	MANE-4920	Aerospace Structures and Controls Laboratory	2
	Professional Development II ³	2		Hum. or Soc. Sci. Elective	4

Fourth Year

Fall		Credit hours	Spring		Credit hours
ENGR-4010	Professional Development III ⁴	1		Capstone Design Elective ⁶	3
MANE-4080	Propulsion Systems	4		Free Elective	4
MANE-4800	Boundary Layers and Heat Transfer ..	3		Free Elective	4
	Flight Mechanics Elective ⁵	4		Free Elective	4
MANE-4910	Fluid Dynamics Laboratory	2			

Humanities or Social Sciences Electives

In this area, the electives are based on the Institute and School of Engineering requirements for these electives. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social

¹ These required courses may be taken in any order.

² Alternative: ENGR-1310.

³ This course will be fulfilled from a list published at the start of each semester.

⁴ Can be taken either semester.

⁵ Choice of: MANE-4090, MANE-4100, or MANE-4200.

⁶ Choice of: MANE-4230, MANE-4850, or MANE-4860.

Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Dual Major Programs

A dual major in Aerospace Engineering and Mechanical Engineering is available to students who follow a prescribed program that can be completed in eight semesters. These students would choose ENGR-1600, ENGR-2350, ENGR-4300, and MANE-4040 as free electives. General requirements and procedures for dual degrees are described within the Academic Information and Regulations section of this catalog.

Nuclear Engineering Curriculum

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. to Engineering Analysis.....	4	PHYS-1100	Physics I	4
MATH-1010	Calculus I.....	4	MATH-1020	Calculus II	4
CHEM-1100	Chemistry I.....	4	ENGR-1600	Materials Science for Engineers	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4
ENGR-1200	Eng. Graphics and CAD ¹	1	ENGR-1300	Engineering Processes or	
			ENGR-1310	Intro. to Eng. Electronics ¹	1

Second Year

Fall		Credit hours	Spring		Credit hours
PHYS-1200	Physics II	4	ENGR-2600	Modeling and Analysis of	
MATH-2400	Intro. to Differential Equations	4		Uncertainty	3
	Free Elective I ²	4	MANE-2830	Nucl. Phenomena for Eng. Appl.	4
	Hum or Soc. Sci. Elective	4	ENGR-2050	Intro. to Eng. Design ³	4
				Hum. or Soc. Sci. Elective	4
			CSCI-1190	Beginning C Programming for	
				Engineers	1

Third Year

Fall		Credit hours	Spring		Credit hours
ENGR-2250	Thermal and Fluids Eng. I	4	MANE-4400	Nucl. Power Systems Engineering	4
ENGR-4300	Electronic Instrumentation ⁶	4	MANE-4480	Physics of Nuclear Reactors	4
MANE-2400	Fundamentals of Nuclear Eng.	4	MANE-4470	Radiological Engineering	4
	Hum. or Soc. Sci. Elective	4		Professional Development II	2
				Technical Elective ⁴	3

Fourth Year

Fall		Credit hours	Spring		Credit hours
ENGR-4050	Mod. and Control of Dynamic Sys. ...	4		Restricted (NE) Elective I	3
MANE-4370	Nuclear Engineering and Eng. Physics			Technical Elective II ⁴	3
	Lab.	4		Restricted (NE) Elective II	3
	Free Elective II	4	MANE-4390	Senior Design Project II	2
MANE-4380	Senior Design Project I	1		Free Elective III	4
ENGR-4010	Professional Development III ⁵	1			

¹ May be taken in any order in the first two semesters.

² Students are encouraged to select a life science course, such as BIOL-1010.

³ Includes Professional Development I.

⁴ Any course in engineering or science at 4000 level or higher.

⁵ Can be taken either semester senior year.

⁶ MANE-4350 may be substituted for this course.

Concentrations

For more information on any of these concentrations, students should consult with their program adviser.

Reactor Physics

This area of concentration is intended for students who wish to develop expertise in the physics of nuclear power reactor cores. Topics such as reactor physics design, nuclear fuel management, and reactor startup physics tests are included.

Reactor Engineering

This area of concentration is intended for students who wish to develop a broad understanding of nuclear technology. Topics such as reactor thermal-hydraulics, reliability, safety and licensing, radioactive waste management, structural dynamics, and materials problems are included.

Health Physics

This area of concentration is intended for students who wish to develop expertise in the radiation safety aspects of nuclear power plant operations and the associated nuclear fuel cycle.

Nuclear Thermal Hydraulics

This area of concentration is intended for students who wish to develop an extended knowledge and the ability to apply principles of fluid mechanics and heat transfer in single-phase and multiphase gas-liquid systems to reactor engineering.

Nuclear Plant Operations and Management

This area of concentration is intended for students who wish to specialize in the operation and management of nuclear power plants. This concentration is directed toward students interested in careers with nuclear electric utility organizations.

Fusion Reactor Engineering

This area of concentration is intended for students who desire to develop expertise in the analysis, assessment, and design of fusion reactor power systems.

Humanities or Social Sciences Electives

In this area, the electives are based on the Institute and School of Engineering requirements. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Dual Major Programs

Dual major programs in Nuclear Engineering and Mechanical Engineering and in Nuclear Engineering and Engineering Physics are available to students who follow prescribed programs that can be completed in eight semesters. Further information is available in the departmental office.

Minor Programs

Students not majoring in nuclear engineering may receive a minor in this discipline by completing 15–16 credit hours of study selected in consultation with their program adviser.

Engineering Physics Curriculum

First Year

Fall		Credit hours	Spring		Credit hours
ENGR-1100	Intro. To Engineering Analysis	4	PHYS-1100	Physics I.....	4
MATH-1010	Calculus I	4	MATH-1020	Calculus II	4
CHEM-1100	Chemistry I.....	4		Science Elective ²	4
	Hum. or Soc. Sci. Elective	4		Hum. or Soc. Sci. Elective	4
ENGR-1200	Eng. Graphics and CAD ¹	1	ENGR-1300	Engineering Processes or	
			ENGR-1310	Intro. to Eng. Electronics ¹	1

Second Year

Fall		Credit hours	Spring		Credit hours
PHYS-1200	Physics II.....	4	ENGR-2600	Modeling and Analysis of	
MATH-2400	Intro. to Differential Equations	4		Uncertainty	3
	Free Elective I ³	4	MANE-2830	Nucl. Phenomena for Eng. Appl.	4
	Hum. or Soc. Sci. Elective	4	ENGR-2050	Intro. to Eng. Design ⁴	4
				Hum. or Soc. Sci. Elective.	4
			CSCI-1190	Beginning C Programming for	
				Engineers	1

Third Year

Fall		Credit hours	Spring		Credit hours
ENGR-2250	Thermal and Fluids Eng. I.....	4	MANE-4400	Nucl. Power Systems Engineering	4
ENGR-4300	Electronic Instrumentation ⁷	4	MANE-4470	Radiological Engineering	4
MANE-4410	Appl. Atomic Nucl. Physics	4		Hum. or Soc. Sci. Elective	4
	Restricted (EP) Elective I.....	4		Professional Development II	2
				Technical Elective I ⁵	3

Fourth Year

Fall		Credit hours	Spring		Credit hours
ENGR-4050	Mod. and Control of Dynamic Sys. ...	4		Restricted (EP) Elective II	3
MANE-4370	Engineering Physics Lab.....	4		Restricted (EP) Elective III	3
	Free Elective II.....	4		Technical Elective II ⁵	3
MANE-4380	Senior Design Project I	1	MANE-4390	Senior Design Project II	2
ENGR-4010	Professional Development III ⁶	1		Free Elective III	4

Concentrations

Radiation Applications

This area of concentration is intended for students who wish to develop expertise in various industrial and other applications of radiation, including radiation damage or enhancement of materials, nondestructive testing, etc.

¹ May be taken in any order in the first two semesters.

² Science Elective: ENGR-1600 or CSCI-1100 (C Programming not necessary after Computer Science I).

³ Students are encouraged to select a life science course, such as BIOL-1010.

⁴ Includes Professional Development I.

⁵ Any course in engineering or science at 4000 level or higher.

⁶ Can be taken either semester senior year.

⁷ MANE-4350 may be substituted for this course.

Radiation Effects on Electronics

This area of concentration is intended for students interested in using radiation techniques to create advanced solid-state electronic circuitry and/or those interested in understanding how optical/electronic devices respond to radiation.

Multiphase Science and Technology

This area of concentration is concerned with applications of fluid mechanics and heat transfer technology to the interactions between mixtures of gases, liquids, and solids.

Fusion Applications

This area of concentration deals with the development and engineering applications of plasmas and the analysis of advanced magnetic confinement and laser-driven fusion power systems.

Humanities or Social Sciences Electives

In this area, the electives are based on the Institute and School of Engineering requirements. Students are urged to elect humanities and social science sequences through which they will obtain adequate breadth and depth in subject areas. Students desiring minors in Humanities and Social Sciences must consult the school or department in which the courses are offered to obtain further information and specific requirements.

Dual Major Programs

A dual major program in Engineering Physics and Nuclear Engineering is available to students who follow a prescribed program that can be completed in eight semesters. Further information is available in the departmental office.

Minor Programs

Students not majoring in engineering physics may receive a minor in this discipline by completing 15–16 credit hours of courses selected in consultation with the program adviser.

Special Undergraduate Opportunities

Program for Graduates of U.S. Navy Nuclear Power Training School

Rensselaer's School of Engineering and its Department of Mechanical, Aerospace, and Nuclear Engineering, in cooperation with the Education for Working Professionals Office and the U.S. Navy, have developed undergraduate degree programs in nuclear engineering and engineering physics for graduates of the U.S. Navy Nuclear Power Training School. Currently, Rensselaer offers programs to personnel stationed at the Kesselring Site in West Milton, New York. These academic programs and resulting degrees are the same as those offered to on-campus students studying this discipline.

Designed to meet the needs of Navy personnel, this program delivers courses and degree programs at a time and place that is convenient to them. Student services are flexible and designed to accommodate the needs of working professionals. Services such as undergraduate admissions and registration are handled entirely by mail, phone, fax, or e-mail. Programs and classes are delivered to Rensselaer's Malta Commons campus, just 20 minutes from the Kesselring Site. The course schedule developed for the program is coordinated with the shift work schedule of the Navy personnel.

The total number of credit hours required for the B.S. degree in either engineering science or nuclear engineering is 128. The curriculum is comprised of 104 engineering and science credits and four professional development credits. Navy students receive up to 31 credit hours of transfer credits for their Navy Nuclear Power Training School course work, leaving 97 credit hours to be completed at Rensselaer.

Courses from other accredited universities may also be considered for transfer. The following is a list of credit transfer courses for graduates of the U.S. Navy Nuclear Power Training School.

ENGR-1300	Engineering Processes.....	1 transfer credit
CHEM-1100	Chemistry I	4 transfer credits
USNA-1010	Military and Its Place in Society	1 transfer credit
USNA-2040	Naval Ship Systems.....	3 transfer credits
ENGR-2050	Intro. to Eng. Design with Prof. Development I.....	4 transfer credits
ENGR-2940	Engineering Project.....	3 transfer credits
ENGR-2960	Topics in Engineering	3 transfer credits
ENGR-4300	Electronic Instrumentation	4 transfer credits
MANE-4440	Critical Reactor Laboratory.....	3 transfer credits
ENGR-4010	Professional Development III	1 transfer credit
MANE-2400	Fundamentals of Nuclear Engineering.....	4 transfer credits

The program has been divided into three trimesters (fall, spring, and summer) each calendar year. Students normally take three courses or 12 credit hours per trimester. Each trimester consists of approximately 15 weeks and averages a two-week break between any two consecutive trimesters. The total of 97 credits can usually be completed in two years plus seven to eight months.

Students with prior credits from other academic institutions may be eligible to transfer them to the present program. Rensselaer's designated academic units are responsible for reviewing and approving such transfers. In addition, students may take a validation exam in selected subjects in place of some regular courses. Academic advisers provide advice and assistance in this regard.

Students must be in residence (i.e., enrolled as full-time students with a minimum of 12 credits per semester) for at least four semesters of their curriculum.

The academic director of this program is Michael Z. Podowski, and the program is administered through the Education for Working Professionals Office.

Graduate Programs

The department offers graduate programs in mechanical engineering, aeronautical engineering, mechanics, nuclear engineering, and engineering physics. To accommodate a student's career plans and interests, the graduate programs are structured to allow great flexibility in choosing appropriate courses, while ensuring sufficient depth and breadth. The professor assigned to or chosen by a student as the adviser has the knowledge to make suggestions of specific courses to further the student's educational goals.

Among the available degrees are the M.Eng., which is perceived to be more practically oriented and consists of course work; the M.S., which is considered more scholarly or fundamental and must include a thesis; and Ph.D. Listed below are many of the requirements for these degrees. For all degrees, full-time students must register each semester for the zero credit course MANE-6900, Graduate Seminar. Complete requirement information is available on the MANE department webpage, <http://www.rpi.edu/dept/mane/deptweb/index.html>

Master's Programs

Master of Science

Students work on a research project in conjunction with a professor who serves as the academic adviser. The topic is chosen based on mutual interests and needs. Course work typically focuses on subjects related to the research project. In addition to the Institute requirements and those listed above, the M.S.

requires a total of 30 credits, six of which come from the thesis. Of the 24 credits of course work, a minimum of 12 must be at the 6000 level with a minimum of nine of these 6000-level courses from MANE (or courses that are cross-listed with MANE courses), and a minimum of 15 credits overall must be from MANE (or courses that are cross-listed with MANE courses). No more than six credits can be from outside of Engineering or Science.

Master of Engineering

M.Eng. students will primarily take courses to deepen and broaden their knowledge, usually in a focused area of study. If a project is included in the degree program, the student will have to involve a professor as an adviser. In addition to the Institute requirements and those listed above, the M.Eng. requires a total of 30 credits. If a project is taken, a minimum of 12 credits of coursework must be taken at the 6000 level with a minimum of nine of these taken within MANE (or courses cross-listed with MANE courses). If no project is undertaken, a minimum of 18 credits must be at the 6000 level, with a minimum of 12 of these taken within MANE (or courses that are cross-listed with MANE courses).

Students must also take part in a culminating experience consisting of:

- an approved sequence of three integrated or related courses with at least two courses in MANE, only one of which may be at the 4000 level. One of these courses must involve a project or design experience which integrates or synthesizes knowledge from other courses taken in the master's program, or
- a six-credit project, or
- an internship/practicum involving a minimum of one summer and one semester full-time work in an approved setting.

Doctoral Programs

For the doctoral degree, 90 credits in addition to the bachelor's or 60 credits in addition to the master's degree are required. Usually, this means that 16 to 20 courses beyond the bachelor's are needed, as specified by the adviser and the doctoral committee, in addition to residence and thesis requirements. Under the guidance of a thesis adviser, the student conducts advanced study and research. If a student chooses to do a thesis with a thesis adviser from another department, a Mechanical, Aerospace, and Nuclear Engineering Department faculty member must be appointed co-chair and the doctoral committee must contain at least two department faculty members. After approximately one year of full-time study, the student should have a research adviser and be advanced to doctoral student status. To attain this milestone a qualifying examination is required. When thesis research has begun and after approximately two years of full-time study, the candidacy examination is taken. At the completion of the research project and after the dissertation has been written, the student must defend the thesis in an open presentation to his or her committee. The degree awarded is the Doctor of Philosophy.

This degree is awarded under the auspices of the Office of Graduate Education when the thesis is directed toward making an original contribution to fundamental knowledge in a particular field or in an interdisciplinary field. A dissertation that is scholarly, creative, original, and publishable may deal also with the relation of a discipline to educational problems and objectives within the field.

Course Descriptions

Courses directly related to all Mechanical, Aerospace, Nuclear Engineering and Engineering Physics curricula are described in the Course Description section of this catalog under the department code MANE.

Engineering at Hartford

Rensselaer at Hartford offers engineering curricula designed to accommodate the evolving needs of the practicing engineer. The curriculum helps students establish and build on a solid theoretical base while allowing them to practice their skills. This blend of academic excellence and industrial experience creates a unique learning environment for engineering students at Rensselaer at Hartford. Degree programs are offered in Mechanical Engineering, Electrical Engineering, Computer and Systems Engineering, and Engineering Science together with graduate certificate programs in Control Systems and High-Temperature Materials.

Engineering Degrees

Master of Engineering and Master of Science degrees are offered in selected engineering disciplines. The Master of Engineering degrees require completion of a three-credit project as a culminating experience while Master of Science degree candidates must carry out research leading to a six-credit thesis. Apart from that, the curricula for both degrees are identical. The Master of Engineering degree is designed to fulfill the needs of practicing engineers in industry while the Master of Science degree is for those focused on a research career.

The following engineering degrees are being awarded:

- Master of Engineering in Computer and Systems Engineering
- Master of Engineering in Electrical Engineering
- Master of Engineering in Engineering Science
- Master of Engineering in Mechanical Engineering
- Master of Science in Electrical Engineering
- Master of Science in Engineering Science
- Master of Science in Mechanical Engineering

Candidates for the master's degree must complete an adviser approved Plan of Study consisting of:

- At least 30 credit hours beyond the bachelor's degree with satisfactory grades.
- At least 18 of the total credit hours presented toward the degree must have the suffix numbers 6000–6990 or 7000–7990.
- At least 21 of the total credit hours presented towards the degree must be from courses taken within the discipline.

Students must prepare their Plan of Study together with their adviser and have it reviewed and approved by the adviser and the Program Coordinator before completion of their fourth course. All the above requirements must be completed within three years of admission.

Culminating Experience (Engineering Project/Engineering Thesis)

The culminating experience is a requirement for the master's degree. It may be fulfilled by any of the following:

- Completing a three-credit-hour master's project along with 27 credit hours of appropriate course work thus leading to the Master of Engineering degree.
- Completing a six-credit-hour master's thesis along with 24 credit hours of appropriate course work thus leading to the Master of Science degree.

Plan of Study

Students must develop a program of study in consultation with their adviser. The program must be recorded in a Plan of Study, which will be reviewed and approved by the adviser and Engineering Area Coordinator. Students must complete this requirement no later than completion of their fourth course. Students who want to deviate from the approved Plan of Study must receive their adviser's approval prior to registration.

To earn the degree, a minimum of six of the major courses (18 credit hours) taken at Rensselaer must be at the advanced level (6000–6990 or 7000–7990).

A limited number of elective courses outside a specific engineering discipline may be taken and credited toward an engineering degree. The student's faculty adviser must approve these elective courses.

Electrical Engineering

The Master's Program in Electrical Engineering allows students to increase their competence in a number of Electrical Engineering subjects, particularly in Digital Communications and Digital Signal Processing, Control Systems, and Communication Networks.

Admission Requirements

Requirements for admission include an undergraduate degree in Electrical Engineering or a closely associated discipline from an accredited institution, a GPA in the upper quartile, and some work experience in a high-technology environment. Additional information on admissions may be found on the Engineering Programs Overview page and on the General Admissions page.

Students with a B.S. degree in another engineering discipline, mathematics, or physics may be admitted subject to fulfillment of the following Electrical Engineering Background Requirements.

Electrical Engineering Background Requirements

Specific background requirements for Electrical Engineering include:

- Advanced Mathematics (i.e., Complex Variables, Laplace Transforms, Fourier Analysis, Probability) (1 term)
- Electronics/Circuits (active or passive) (1 additional term)
- Linear systems or Feedback Systems (1 term)
- Digital Logic (1 term)
- Technical Design Elective (e.g., Communications Systems, Control Systems Engineering, Computer Networks) (1 term)

Students lacking any of the above courses must consult with their adviser to devise a plan for corrective action.

M.Eng. in Electrical Engineering Program Requirements

The Master's degree is awarded on successful completion of the following:

Required Core (15 credits)

ECSE-4500	Probability for Engineering Applications	ECSE-6560	Digital Communications Engineering
ECSE-6400	Systems Analysis Techniques	ECSE-6620	Digital Signal Processing
		ECSE-6980	Engineering Project

Electives (15 credits)

ECSE-4440	Control Systems Engineering	ECSE-6630	Digital Image and Video Processing
ECSE-4490	Fundamentals of Robotics	ECSE-6660	Broadband and Optical Networking
ECSE-4670	Computer Communication Networks	ECSE-6590	Principles of Wireless Communications
ECSE-4770	Computer Hardware Design		
ECSE-6050	Advanced Electronic Circuits	ECSE-6960	Topics in Electrical Engineering, LANs, MANs, and Internetworking
ECSE-6410	Robotics and Automation Systems		
ECSE-6420	Nonlinear Control Systems	ECSE-6960	Topics in Electrical Engineering, Embedded Digital Control Systems
ECSE-6440	Optimal Control Theory		
ECSE-6460	Multivariable Control Systems		

Specializations

From the elective courses currently available at Hartford, a three-course specialization can be constructed in any of the following areas:

- Digital Communications
- Digital Signal Processing
- Control Systems
- Communication Networks

M.S. in Electrical Engineering Program Requirements

The M.S. requirements are the same as those for the M.Eng. in Electrical Engineering, except for the substitution of a 6-credit-hour thesis (ECSE-6990) in place of one elective and the three-credit-hour project.

The student may propose other areas, but they are subject to adviser's approval.

Please contact Professor Farooque Mesiya at mesiya@rh.edu if you have any questions about the electrical engineering program.

Computer and Systems Engineering

The Master of Engineering in Computer and Systems Engineering provides the student with the appropriate hardware and software tools needed in such critical areas as digital communications and signal processing, robotics and automation systems, computer communication networks, and software engineering.

Admission Requirements

Students should have received a Bachelor of Science degree in Electrical Engineering, Computer Engineering, or Computer Science. Students with a B.S. degree in another engineering discipline, Mathematics, or Physics, are subject to the condition that the following essential prerequisites (or their equivalents) for their chosen area of specialization have been completed:

Digital Communications and Signal Processing

ECSE-2010	Electrical Circuits
ECSE-2410	Signals and Systems
ECSE-2610	Computer Components and Operations

Computer Communications Networks

ECSE-2010	Electrical Circuits
ECSE-2410	Signals and Systems
ECSE-2610	Computer Components and Operations

Required Core (15 credits)

ECSE-4500	Probability for Engineering Applications
ECSE-4670	Computer Communication Networks

Electives (15 credits)

ECSE-4440	Control Systems Engineering
ECSE-4490	Fundamentals of Robotics
ECSE-4670	Computer Communication Networks
ECSE-4770	Computer Hardware Design
ECSE-6400	System Analysis Techniques
ECSE-6410	Robotics and Automation Systems
ECSE-6420	Nonlinear Control Systems
ECSE-6440	Optimal Control Theory
ECSE-6460	Multivariable Control Systems
ECSE-6560	Digital Communications Engineering
ECSE-6630	Digital Image and Video Processing
ECSE-6660	Broadband and Optical Networking
ECSE-6770	Software Engineering I
ECSE-6780	Software Engineering II

Robotics and Automation Systems

ECSE-2010	Electrical Circuits
ECSE-2410	Signals and Systems
ECSE-2610	Computer Components and Operations

Software Engineering

CSCI-1100	Computer Science I
CSCI-2300	Data Structures and Algorithms
ECSE-2610	Computer Components and Operations

ECSE-4440	Control Systems Engineering OR CSCI-4210 Operating Systems
ECSE-6620	Digital Signal Processing
ECSE-6980	Engineering Project

ECSE-6590	Principles of Wireless Communications
ECSE-6960	Topics in E.E.: LANs, MANs and Internetworking
ECSE-6960	Topics in E.E. Embedded Digital Control Systems
ECSE-6960	Topics in E.E.: Cryptography and Network Security
ECSE-7010	Optical Fiber Communications
ECSE-7100	Real-Time Programming and Applications
MANE-6960	Topics in Mechanical Engineering Sensors and Activators

Specializations

From the courses currently available at Hartford, a three-course specialization can be constructed in any of the following areas.

- Digital Communications and Signal Processing
- Computer Communication Networks
- Robotics and Automation Systems
- Software Engineering

The student may propose other areas, but they are subject to adviser's approval.

Preparatory courses do not apply toward the minimum 30 credit hours required for the Master of Engineering degree.

Please contact Professor Farooque Mesiya at mesiya@rh.edu if you have any questions about the computer and systems engineering program.

Engineering Science

The Engineering Science curriculum serves students whose educational needs do not correspond to the standard professional engineering curricula. It allows students to tailor courses of study to their particular requirements. Each student's course of study is developed in close consultation with the adviser to allow meaningful and strongly directed interdisciplinary approach. The degree awarded in this area is not, nor is it intended to be, accredited for practice. Students entering the Engineering Science program are expected to have fulfilled the General Engineering Requirements noted above.

Please contact Professor Ernesto Gutierrez-Miravete at ernesto@rh.edu if you have any questions about the engineering science program.

Mechanical Engineering

The Master of Science in Mechanical Engineering allows the student to increase his or her competence in a number of mechanical engineering subjects, or to specialize in depth in the areas of fluid mechanics, heat transfer, mechanical design, solid mechanics, or thermodynamics.

Requirements for admission include an undergraduate degree in Mechanical Engineering or a closely associated discipline from an accredited institution, a GPA in the upper quartile and some work experience in a high technology environment. Detailed admission policies are also available on the internet at: www.rh.edu/engr/eng_admission.html.

Students with a B.S. degree in another engineering discipline, mathematics, or physics may be admitted subject to fulfillment of the following Mechanical Engineering Background Requirements.

Mechanical Engineering Background Requirements

- Chemistry (One additional term)
- Statics (One term)
- Dynamics (One term)
- Strength of Materials (One term)
- Fluid Mechanics (One term)
- Heat Transfer (One term)
- Machine Design (One term)
- Thermodynamics (Two terms)
- Systems and Controls (One Term)

Students lacking any of the above courses must work closely with their adviser to devise plans for corrective action.

Mechanical Engineering Program Requirements

The Master's degree is awarded on successful completion of the following:

Required Core (15 credits)

MANE-5000	Advanced Engineering Math I	MANE-7100	Mechanical Engineering Foundations II (Solids-Materials)
MANE-7000	Advanced Engineering Math II		
MANE-5100	Mechanical Engineering Foundations I (Thermo-Fluids)	MANE-6980	Mechanical Engineering Project (culminating experience)

Electives from any of four Concentration Areas (15 credits)

SOLIDS

MANE-4240	Introduction to Finite Elements
MANE-4610	Vibrations
MANE-4650	Fracture Mechanics
MANE-6180	Mechanics of Composite Materials
MANE-6200	Plates and Shells
MANE-6960	Advanced Topics in Finite Element Analysis

FLUIDS

MANE-4800	Boundary Layers and Heat Transfer
MANE-5060	Introduction to Compressible Flow
MANE-5080	Turbo machinery
MANE-6530	Turbulence
MANE-6550	Theory of Compressible Flow
MANE-6720	Computational Fluid Dynamics

THERMAL SYSTEMS

MANE-6540	Advanced Thermodynamics
MANE-6630	Conduction Heat Transfer
MANE-6640	Radiation Heat Transfer
MANE-6650	Convection Heat Transfer
MANE-6840	An Intro. to Multiphase Flow and Heat Transfer
MANE-6830	Combustion

MANUFACTURING AND MATERIALS

MTLE-4260	High Temperature Alloys
DSES-6110	Introduction to Applied Statistics
MTLE-6960	High Temperature Coatings Engineering
MTLE-7061	Casting and Joining Processes

Students must work closely with their adviser to decide whether to focus on one of the above concentration areas or take electives from all of them. A limited number of elective courses outside the area of mechanical engineering are permitted. However, the student's adviser must approve these courses prior to them being taken.

Please contact Professor Ernesto Gutierrez-Miravete at emesto@rh.edu if you have any questions about the mechanical engineering program.

Graduate Certificate in Control Systems

Control systems are widely used in engineering to monitor the values of process variables by measurement so as to make rational decisions about required corrective actions. Analysis and design of control systems requires consideration of sensors, controllers, transmitters, as well as auxiliary control and hardware elements.

Rensselaer offers a Certificate of Advanced Studies in Control Systems designed to provide an understanding of control systems engineering, including the fundamental principles of control systems and their application to real-life engineering problems.

The Certificate of Advanced Graduate Studies in Control Systems is awarded on successful completion of the following courses:

Core Courses (6 credits):

ECSE-4440	Control Systems Engineering	ECSE-6400	Systems Analysis Techniques
-----------	-----------------------------	-----------	-----------------------------

Elective Courses (Any two, 6 credits)

ECSE-4490	Fundamentals of Robotics	MANE-6960	Sensors and Actuators in Mechatronics
ECSE-6420	Nonlinear Control Systems	ECSE-6960	Special Topics in Electrical Engineering, Embedded Digital Control Systems
ECSE-6440	Optimal Control Theory	ECSE-6480	Adaptive Systems
ECSE-6460	Multivariable Control Systems		

Academic credit earned from these courses can then be applied towards a Master's degree.

Please contact Professor Farooque Mesiya at mesiya@rh.edu if you have any questions about the Control Systems Certificate Program.

Interdisciplinary Degree Programs

Rensselaer has long understood that neither student career interests nor modern industry needs are easily pigeonholed into a single discipline. In fact, the discovery of new and more advanced technologies more often than not results from combining the knowledge of a variety of disciplines. Rensselaer is, therefore, resolved to become a leader in providing numerous opportunities for interdisciplinary study.

In keeping with this commitment, the School of Engineering has developed a variety of special programs that bridge one or more departments or even Institute schools. These include both degree and research programs that allow students to develop a breadth and depth of knowledge in more than one discipline. By their nature, these programs are highly flexible and often involve working in teams with faculty and students representing multiple disciplines.

In addition to opportunities in the School of Engineering described below, other interdisciplinary programs available at Rensselaer are listed in the Interdisciplinary Studies Index of this catalog and are described fully in the section pertaining to the associated Institute school or division.

Engineering Science

Chair: Richard N. Smith (Interim)

Rensselaer's graduate Engineering Science program serves students whose educational desires do not correspond to the standard professional engineering curricula. Although no B.S. degree is offered in Engineering Science, M.S. and Ph.D. degrees are awarded to students whose programs of study are truly multidisciplinary. The M.S. degree in Engineering Science is reserved for students who are pursuing their program of study through the Education for Working Professionals core enterprise (either Distance Learning or Rensselaer at Hartford). The requirements for this program may be found in this Catalog in the School of Engineering section under the heading Engineering at Hartford. The Doctor of Philosophy (Ph.D.) degree in Engineering Science is awarded by the School of Engineering for genuine multidisciplinary research. The degree is earned once the student's dissertation adviser and doctoral committee agree that the student has demonstrated independent thought and research, has made original contributions to the fundamental knowledge in a given interdisciplinary field, and has produced a substantial body of information in the form of a dissertation, aspects of which are publishable in a refereed journal. Since each student develops an individual program in consultation with a faculty adviser, the program provides the opportunity to tailor programs of study to specific needs. Studies may be based on the sciences. For example, programs may concentrate on the application of engineering and scientific techniques to areas between technology and the humanities and social sciences. The general requirements for the Ph.D. in Engineering Science may be found in the Catalog chapter on Academic Information and Regulations under the heading Doctoral Degree. Specific information pertaining to the Engineering Science doctoral program is available from the Office of Academic and Student Affairs in the School of Engineering.

Product Design and Innovation

Chair: Mark W. Steiner (Interim)

Chair: Sharon Anderson-Gold (Interim)

This dual major program, which the Schools of Engineering and Humanities and Social Sciences offer jointly, satisfies the requirements for the Bachelor of Science programs in both Mechanical Engineering and Science, Technology, and Society (STS). Product Design and Innovation (PDI) prepares students to become innovative designers who will develop and design the advanced products and technologies needed in the future. Built around a design studio every semester, PDI combines the technical sophistication of Rensselaer's engineering curriculum with the insight and vision of the humanities and social science disciplines in the STS curriculum.

The design studio that students take every semester is the PDI core, which gives them a hands-on opportunity to bring together the two major curricula. The engineering curriculum provides a fundamental education in engineering science through basic courses in engineering mechanics, engineering electronics, energy, materials, and manufacturing. The STS curriculum provides a fundamental education in the economic, ethical, cultural, and political dimensions of product development and innovation, including numerous case studies of successes and failures that help students learn what it takes to be effective leaders of design teams. Through the design studios, students explore and develop their creativity while building a portfolio of design experiences continuously throughout all four years.

The design experiences range from larger systemic problems to smaller focused problems, so that students have broad exposure to different applications of design practice. Some fall and spring semester studios are taught as a sequence to give students experience with the design process from beginning to implementation. The studios also develop students' skills in using computers and other advanced tools and techniques, as well as in drawing, visualizing, communicating, and working together.

PDI graduates are thus uniquely prepared to put their creativity to work as leaders of design and innovation, whether in a multinational business at the cutting-edge of the global market or in a smaller business that creates an unusual solution to a local problem. They are able to function effectively in the new situations and unfamiliar environments of a multicultural global society, to collaborate with diverse constituencies to analyze and formulate problems of varying complexities, and to work individually and in teams to develop truly innovative and powerful solutions to challenges affecting this country's continued prosperity and social well-being. Programs corresponding to PDI are described in the School of Architecture and the Humanities and Social Sciences STS Department sections of this catalog.

Product Design and Innovation Curriculum

First Year

Fall		Credit hours	Spring		Credit hours
IHSS-2200	Design Studio I	4	ENGR-2020	PDI Studio II ²	4
STSH-1110	Introduction to STS (First-Year Studies)	4	ENGR-1100	Introduction to Engineering Anal.	4
MATH-1011	Calculus I	4	MATH-1020	Calculus II	4
CHEM-1100	Chemistry I	4	ENGR-1300	Engineering Processes ¹	1
ENGR-1200	Engineering Graphics and CAD ¹	1	STSS-2960	Design Culture and Society	4
		17			17

Second Year

Fall		Credit hours	Spring		Credit hours
IHSS-2500	Design Studio III ³	4	ENGR-2050	Intro. to Engineering Design	4
ENGR-1600	Materials Science for Engineers	4	ENGR-2530	Strength of Materials	4
MATH-2400	Introduction to Differential Equations	4	ENGR-2090	Engineering Dynamics	4
PHYS-1100	Physics I for Engineers	4	PHYS-1200	Physics II for Engineers	4
CSCI-1190	Programming	1			16
		17			

Third Year

Fall		Credit hours	Spring		Credit hours
ARCH-4960	Design Studio V ⁴	4	ENGR-4960	Design Studio VI	4
STSS-4xxx	STS Advanced Option ⁵	4	STSS-4xxx	STS Advanced Option ⁵	4
ENGR-2710	General Manufacturing Processes	3	ENGR-4050	Modeling and Control	4
ENGR-2350	Embedded Control	4	ENGR-2550	Thermo/Fluids Engineering I	4
ENGR-2600	Modeling and Analysis of Uncertainty	3			16
		18			

Fourth Year

Fall		Credit hours	Spring		Credit hours
MANE-4260	Design of Mechanical Systems	3	MANE-4940	Design Studio VIII	4
MANE-4030	Elements of Mechanical Design	4	ENGR-4300	Electronic Instrumentation	4
MANE-4040	Mechanical Systems Lab	2	MANE-4010	Thermo Fluids Engr. II	4
MANE-4908	STS Senior Project ⁷	4	MANE-4020	Thermo Fluids II Lab	2
STSS-4800	Public Service Internship ⁶	4	ENGR-4010	Professional Development III	1
		17			15

¹ These courses may be taken in any order.

² PDI II, V, VI, and GMP satisfy the mechanical engineering requirement for the concentration electives in Product Design and Innovation.

³ For PDI students, IHSS-2500 can be used as a substitute for the second-year requirement in the STS area option.

⁴ PDI II, V, VI, and GMP satisfy the mechanical engineering requirement for the concentration electives in Product Design and Innovation.

⁵ Candidate courses include STSS-4350; STSS-4960; STSS-4960; STSH-4230; STSS-4110; STSS-4250; STSS-4310; STSS-4560; and STSS-4650.

⁶ This course satisfies the requirement for Professional Development II.

⁷ The STS Senior Project can be combined with the PDI Capstone Design Studio to make an 8-credit capstone studio project. Coordination should be done with your PDI adviser.

Interdisciplinary Research Centers

Center for Earthquake Engineering Simulation

Director: Ricardo Dobry

Associate Director: Tarek Abdoun

Assistant Director for Training and Outreach: Thomas Zimmie

The Center for Earthquake Engineering Simulation is part of NEES (Network for Earthquake Engineering Simulation), an NSF initiative aimed at revolutionizing earthquake engineering research in the United States. NEES has merged experimental laboratory and field research with analytical simulations at a number of university facilities, electronically linking them into a national Collaboratory. Between 2000–2004, the National Science Foundation (NSF) invested more than \$80 million to construct the Collaboratory. Today it includes 15 experimental sites or "nodes" plus the UC San Diego Supercomputer Center and the NEES Consortium located in Davis, CA. Rensselaer is a node in NEES network and a partner in the node at Cornell University. As a result of Rensselaer's designation as a node, the campus-based 150 g-ton geotechnical centrifuge facility was upgraded and expanded. The facility is now home to tele-participation tools including state-of-the-art telecontrol and teleconference rooms enabling researchers to conduct real-time experiments between Rensselaer and other NEES experimental and computational facilities via high-speed internet connections. The Center for Earthquake Engineering Simulation is also home to a 1 g seismic shaking table, 1.6 m x 2.6 m in plan, that is primarily utilized for structural engineering research.

As part of a 10-year initiative started in October of 2004, NEES facilities will be used in innovative earthquake research, including use of the CEES by Rensselaer faculty and outside researchers working on campus, or via tele-participation tools. To date, Rensselaer, in partnership with Cornell, has already received one of the coveted 10 initial NEES research grants. This grant is supporting a 4-year project on buried pipelines subject to permanent ground deformation, such as at fault crossing locations. In addition, a number of other currently supported research projects focus on:

- the development of wireless sensors and sensor networks to measure ground accelerations and deformations in both lab and field,
- the seismic response of pile foundations to liquefaction,
- the effect of blasting on earth embankments,
- the numerical modeling of soil compaction using micro mechanics, and
- the development of additional tools for existing in-flight centrifuge robot
- the numerical modeling and analysis of metal buildings subjected to seismic loads.

Affiliated Faculty

T. Abdoun, A. Abouzeid, S. Derby, R. Dobry, M. O'Rourke, M. Symans, M. Zeghal, T. Zimmie

Flexible Manufacturing Center

Co-Directors: Stephen J. Derby, Raymond H. Puffer, Jr.

FMC Home Page: <http://www.fmc.rpi.edu>

The mission of the Flexible Manufacturing Center (FMC) is to conduct research and education related to modular, flexible manufacturing systems and processes. An increasingly competitive global environment has led to ever shorter product life cycles. Flexible manufacturing systems and processes are necessary to cost effectively produce under these conditions. Flexibility during process operation accommodates a broad product mix, while flexibility in overall system design will accommodate product and process reconfiguration and redeployment. The FMC has also been involved with many projects dealing with materials that are themselves flexible.

The objectives of the FMC are to: develop solutions for manufacturing research problems using a team of interdisciplinary scientists and engineers; provide both graduate and undergraduate students with a unique educational opportunity to conduct R&D and gain experience solving industrially relevant problems and prepare them to “hit the ground running” in key technical positions in industry; advance state-of-the-art in flexible, energy efficient and environmentally friendly manufacturing processes; develop underpinning technologies required to support manufacturing a flexible product mix with short cycle times; serve as a model for industry/university/government partnership to solve societal problems; and build long-term relationships with clients of all sizes to become their “manufacturing and process R&D lab.”

Current research projects include; manufacturing processes and systems for high temperature proton exchange membrane fuel cell components; automation of pattern assembly for investment casting; automated handling of contact lenses during manufacture and inspection; vision based inspection of contact lenses; material handling of limp and viscous materials; laser processing of flexible materials; and peak load management systems development. FMC researchers have also conducted numerous short term projects for manufacturers in collaboration with the NASA Space Technology Outreach Program (SATOP).

Affiliated Faculty/Staff:

K. Anderson, B. Benicewicz, S. Chiappone, K. Craig, S. Derby, G. Eisman, M. Jensen, R. Puffer, S. Rock, L. Ruff, M. Steiner, J. Tichy, D. Walczyk

Center for Image Processing Research

Director: William A. Pearlman

Associate Director: John W. Woods

CIPR Home Page: <http://www.cipr.rpi.edu>

The Center for Image Processing Research (CIPR) conducts a range of research and academic programs in image and video processing. Faculty participants represent a number of academic disciplines and, together with their students, provide the nucleus for ongoing activities within CIPR. In addition to providing an intellectual focus for image-processing activities at Rensselaer, the objectives are to provide a positive impact on graduate and undergraduate programs, to support ongoing activities with a world-class infrastructure, and to enhance its reputation as one of the world’s premier image-processing research centers. Current CIPR research areas include image modeling, computer vision and image analysis, document analysis and processing, image and video enhancement and reconstruction, biomedical image processing, computer graphics, computational geometry, image and video compression and transmission,

virtual video synthesis, visualization and display techniques, and multimedia systems. The CIPR has administrative authority over and shares infrastructure with the NSF Industry/University Center for Next Generation Video (CNGV) and the NSF Engineering Research Center for Subsurface Sensing and Imaging System (CenSSIS) at Rensselaer. These centers have some joint research programs with CIPR, but otherwise operate independently of CIPR.

Affiliated Faculty

C. Carothers, R.W. Franklin, L. Gerhardt, S. Kalyanaraman, G. Nagy, W.A. Pearlman, R. Radke, K. Rajan, B. Roysam, K.S. Vastola, J.W. Woods, X.-C. Zhang

Center for Infrastructure and Transportation Studies

Director: William A Wallace (Acting)

CITS Home Page: <http://www.rpi.edu/dept/cits>

The Center for Infrastructure and Transportation Studies (CITS) provides a focal point for campus research addressing the world's infrastructure and transportation needs. CITS also assists in coordinating all related pedagogical initiatives. About 15 faculty across the Institute participate.

The Center's research program focuses on five themes: intelligent transportation systems, information technology, deployment, and application, network analysis and control, asset management, and advanced materials. Each aspect of the life cycle for infrastructure and transportation systems is of interest—planning, analysis, design, maintenance, operation, preservation, restoration, and renewal. Common infrastructure focal points are roadways, bridges, and power distribution networks.

Projects currently under way include wireless ATIS systems, incident management systems, critical infrastructure interdependencies, investment planning for multimodal freight networks, capacity analyses for highway facilities, multilayer network modeling, and advanced concrete technologies. The pedagogical activities include course material development in the areas of intelligent transportation systems and asset management.

Affiliated Faculty

A. Balfour, D. Berg, J. Chow, K. Connor, A. Desrochers, R. Dobry, G. Dvorak, M. Embrechts, J. Holguin-Veras, C. Hsu, M. Kalsher, S. Komisar, H. Littman, C. Malmborg, R. Messler, D. Millard, L. Myrabo, G. Nagy, K. Nelson, M. O'Rourke, J. Plawsky, M. Raghavachari, S. Salon, G. Saulnier, M. Shephard, J. Tien, S. Ukkusuri, D. Vitaliano, W. Wallace

Research Associate: E. Lee

Research Engineer: J. Wojtowicz

Administrative Staff: J. Pertierra

Center for Multiphase Research

Director: Michael Z. Podowski

CMR Home Page: <http://www.ne.rpi.edu/cmr>

In this country, Rensselaer's interdisciplinary Center for Multiphase Research (CMR) is the premier research center of its kind. The CMR has assembled a large and dynamic group of scientists and engineers dedicated to exploring and exploiting new developments in every conceivable aspect of multiphase flow and heat transfer technology. The CMR coordinates the diverse activities of these researchers and facilitates the cross-disciplinary exchange of information as well as technology transfer to industry.

Multiphase flow occurs in any physical process or industrial system involving more than one phase (solids, liquids, and vapors). Multiphase flow and related heat transfer technology are the keys to increasing the productivity and efficiency of many American industries. Indeed, this technology underlies our understanding of crystal growth, foundry casting, high-power density electronic cooling, chemical processing, petroleum refining, and slurry and pneumatic transport. Multiphase technology also has basic applications to aircraft wing icing, deep-sea mining, aseptic food processing, pharmaceutical manufacturing, refrigeration and air conditioning, chemical and nuclear reactor safety, foam production, aerosols, particulate erosion, combustion, processing and propulsion in outer space, enhanced petroleum recovery and bioreactors. Moreover, there are many important defense applications for this technology.

Historically, multiphase flows have been analyzed empirically. As a result, these analyses necessarily included many uncertainties and inaccuracies. Thus, the design and operation of phase change equipment had to include large margins. Recent developments in supercomputing, symbolic manipulator algorithms, diagnostic instrumentation, and applied mathematics have driven revolutionary changes in scientists' ability to understand and predict multiphase flow phenomena.

The research activities of the CMR involve faculty, staff, and graduate students of many backgrounds who work synergistically on relevant multiphase research. Some typical research projects are:

- Conducting crystal growth experiments in outer space.
- Developing state-of-the-art laser optical diagnostic system for measuring multidimensional phenomena.
- Developing CFD models of multiphase flows.
- Predicting critical heat flux (CHF) using first principle models.
- Understanding instability phenomena in various phase change systems.
- Investigating laser materials processing, thin film behavior, and ultrahigh boiling heat fluxes.
- Imaging interfacial structures in gas/liquid flows.
- Assessing the consequences of hypothetical nuclear reactor accidents.

The members of the center represent a broad spectrum of science and engineering disciplines and have access to a wide variety of equipment and computational power.

Affiliated Faculty

S. Antal, G. Belfort, A.E. Bergles, D. Drew, J.E. Flaherty, W. Gill, M. Glicksman, A. Hirska, K. Jansen, M. Jensen, D. Kaminski, R.T. Lahey Jr., H. Littman, R.I. Nigmatulin, A. Ostrogorsky, M.Z. Podowski, M.S. Shephard, R. Smith, D. Sperber, B. Szymanski, P. Wayner

Center for Subsurface Sensing and Imaging Systems

Director: Badrinath Roysam

CenSSIS Home Page: <http://www.ecse.rpi.edu/censsis>

The Center for Subsurface Sensing and Imaging Systems (CenSSIS) is a National Science Foundation Engineering Research Center (NSF-ERC) that conducts multidisciplinary research on common solutions to diverse problems for sensing and imaging objects that are hidden under a surface. This is part of a larger center involving Northeastern University, Boston University, University of Puerto Rico at Mayagüez, and several affiliate institutions including The Woods Hole Oceanographic Institute, Memorial Sloan-Kettering Cancer Center, Massachusetts General Hospital, Idaho National Engineering and Environmental Laboratory, and Lawrence Livermore National Laboratory. Examples of applications include deep confocal laser-scanning microscopy of minute subcellular objects, electrical impedance tomography of the human body and underground waste sites, retinal imaging, surgical planning for radiation treatment, and inspection of hidden defects in roads and bridges. These diverse applications are addressed using advanced computer algorithms for tomographic image reconstruction, image analysis, and computer vision. Some projects involve design and fabrication of working prototypes using advanced electronics, processors, and embedded algorithms. Graduate and undergraduate students participate on various projects at the center. Opportunities also exist for qualified K-12 students to participate in selected projects.

Affiliated Faculty

K. Bennett, C. Carothers, M. Cheney, D. Isaacson, J. Newell, R. Radke, B. Roysam, G. Saulnier, C. Stewart, B. Yazici, X.-C. Zhang