Department of Paper and Bioprocess Engineering

GARY M. SCOTT, Chair
205 Walters Hall, 315-470-6501 FAX 315-470-6945

www.esf.edu/pbe

Participating Faculty

AMIDON (Biorefinery, Fiber Properties, Paper Properties, Management, Pulping, Bleaching, Deinking), BUJANOVIC (Chemistry of Lignocellulosics and Products, Lignin Structure and Reactivity, Pulping, Bleaching), S. CHATTERJEE (Transport Phenomena, Design, Simulation, Pollution Abatement), DOELLE (Papermaking, Paper Fillers, Recycling, Renewable Energy, Bioprocesses, CO2 Reduction), FRANCIS (Bioenergy, Chemical Engineering, Pulping), LAI (Chemistry of Wood, Pulping, and Bleaching, Lignin Reactivity and Utilization, Biomass Fractionation, Bioproduct Development), LIU (Upstream and Downstream Bioprocess Bioengineering, Fermentation, Kinetics, Separation, Pulping, Bleaching, Fiber Properties), RAMARAO (Chemical Engineering, Instrumentation, Flow Phenomena, Process Control), SCOTT, Chair (Biotechnology, Bioprocess Engineering, Paper Machine Operations, Recycling, Modeling)

The paper engineering, paper science, and bioprocess engineering programs provide a broad base of study in the field of paper and biobased products to prepare graduates for professional positions in the pulp, paper, bioenergy, biochemicals, biomaterials, bioproduct, pharmaceutical, and other industries. This biobased industry is the fifth largest in the nation and is very strong internationally. The College pioneered instruction for the pulp and paper industry in 1920 with the formation of a paper science and engineering department and has maintained a leading position in this area of professional education. Recently, the department's pioneering efforts have led to new technologies in the biorefinery, biochemical, and bioprocessing areas. The expanded bioprocess engineering program is one of the first of its kind in the United States.

These programs have a longstanding reputation for preparing graduates for such rewarding positions as research chemists, biotechnology scientists, process engineers, technical service representatives, and managers. Graduates have advanced to positions of leadership in research, management, technical operations, and sales in the pulp and paper industry as well as allied industries of heavy equipment manufacture, process chemicals, and other biobased industries. Other graduates have gone on to successful careers in medical, chemical and other varied fields.

The programs provide education in the physical sciences and chemical engineering, with specific emphasis on those aspects that relate to the sustainable manufacture of pulp and paper, and other products from wood and other lignocellulosic materials. This includes the chemistry, anatomy, and components of wood; the conversion of wood to pulp, paper, and other products; the chemistry and physics of paper and paper formation, and the industrial utilization of biological processes and sustainable raw materials. The engineering programs include the basics of chemical engineering with a foundation of unit operations and specialized courses, for example, in air and water pollution abatement from an industrial perspective. The paper engineering program extends this foundation to present a chemical engineering education tailored specifically to the pulp and paper industry. The bioprocess engineering program extends a chemical engineering education with a focus on biomass feedstocks and biological processes rather than a focus on petroleum. The industry is now using advanced chemistry and biotechnology to improve its utilization of renewable carbon and hydrogen in lignocellulosics. The paper science program takes a more science-based (e.g., chemistry or biology) approach to the study of pulp and paper systems. With the science program, students are able to more deeply explore a particular aspect of the industry. The paper engineering and paper science programs have identical first years, allowing students to switch between programs without loss of course credits. Similar lower-division schedules among all three programs allow students to switch programs with only minimal disruption.

The paper engineering program is accredited by the Engineering Accreditation Commission/Accreditation Board for Engineering and Technology (EAC/ABET).

Facilities

The Department of Paper and Bioprocess Engineering is located in Walters Hall, which is devoted to education and research in pulp, paper, bioproduct, bioenergy, and allied fields. In addition to a large number of special purpose laboratories and highly sophisticated scientific equipment, there is a pilot plant equipped with machinery and instrumentation for studies of pulping, pulp cleaning and screening, recycling, refining, and papermaking. Equipment includes two complete paper machines, one 48-inch and one 12-inch; two pressurized refiners for mechanical pulping; and auxiliary equipment. An environmental engineering laboratory includes various methods of paper recycling and waste treatment. A state-of-the-art laboratory for testing paper and other materials is in service. A modern bioprocess engineering lab includes fermenters, spectrophotometer, shakers, anaerobic chamber, incubators, autoclaves, bio- and chemical reactors. Pilot facilities also include equipment for the biological treatment and the separation processes for production of specialized chemicals and polymers from wood, including a 400-liter fermenter, nanoseparation equipment, and incubators for the growth of ligninolytic organisms. This equipment, as well as the extensive chemical engineering laboratory, is employed for both education and research. Computer hardware and software are continually updated for teaching and research in process control and simulation.

Bachelor of Science in Bioprocess Engineering

The bioprocess engineering program prepares students for careers as engineers and scientists in biological and process-related fields, filling positions that are typically filled by chemical engineers following additional education, specifically in biotechnology. As we begin the 21st century, growth and development worldwide will need to be done in an ecologically friendly manner that looks to the long-term future of the environment. The bioprocess engineering program seeks to educate engineers versed in the traditional chemical engineering fields with a focus on developing chemicals, commodity and specialty products, and energy from sustainable sources, especially from wood and other lignocellulosic materials rather than non-renewable sources such as fossil fuels.

Students study a broad base of topics including the fundamentals of engineering focused on the chemical and biological processing of raw materials, especially from renewable and sustainable sources. Emphasis in this program is on using renewable biomass resources to replace petroleum in energy and industrial product applications. Examples of such technology include the sustainable production of ethanol, acetic acid, polymers, and other chemicals that have traditionally been produced from fossil fuels such as oil, coal, and natural gas.

Students gain valuable experience through a capstone design experience in which they work on significant problems in the design and implementation of new technologies. In addition, a summer internship is required of all students during which they gain valuable skills and experience in terms of technical knowledge and professional development. Both of these experiences serve to integrate the knowledge gained in their coursework with real-world work experiences commonly seen in their first positions after graduation.

The curriculum consists of a number of categories of courses. The general education component, which is required of all ESF students, broadens the students' perspectives on global and societal issues, an important component of any education. Students also take a number of courses in math and the basic sciences — chemistry, physics, and biology — to provide the background for the courses that prepare students for engineering practice. The engineering courses cover a variety of topics that are traditional for a chemical engineering program, supplemented with courses specific to bioprocess engineering. Students are encouraged to select courses concentrated in a specific area: Biomolecular Engineering, Biochemical Engineering, Biopolymer Engineering, Bioenergy Engineering, or Environmental Engineering.

Students may be admitted to the bioprocess engineering program as first-year students with appropriate science backgrounds from their high school or as transfer students at any level with accommodations for coursework requirements. Students who have the associate degree in engineering science, chemical technology, biological sciences, or general science and mathematics are encouraged to apply as transfer students.

Undergraduate Program Requirements

Lower Division Required Courses (52 credits)

Courses			Credits	
APM	153	Computing Methods Professional education course	PE	3
APM	485	Differential Equations for Engineers and Scientists *Math course*	M	3
BPE	132	Orientation Seminar: Bioprocess Engineering *Engineering science course*	ES	1
CLL	190	Writing and the Environment *Meets the requirements for general education skills and knowledge area. A complete listing of ESF or Syracuse University courses that meet the general education standards established by SUNY is listed in Undergraduate Education.*	G	3
CLL	290	Writing, Humanities, and the Environment	G	3
EFB	103/104	General Biology II and Laboratory *Natural science course*	G,NS	4
FCH	150/151	General Chemistry I and Laboratory	NS	4
FCH	152/153	General Chemistry II and Laboratory	NS	4
FCH	221/222	Organic Chemistry I and Laboratory	NS	4
FCH	223/224	Organic Chemistry II and Laboratory	NS	4
FOR	207	Introduction to Economics	G	3
MAT	295	Calculus I	G,M	4
MAT	296	Calculus II	M	4
MAT	397	Calculus III	M	4
PHY	211/221	General Physics I and Laboratory	G,NS	4

Electives (12 credits)

General Education Course: American History	G	3
General Education Course: Western Civilization	G	3
General Education Course: Other World Civilization	G	3
General Education Course: The Arts	G	3

Upper Division Required Courses (39 credits)

APM	391	Introduction to Probability and Statistics	M	3
BPE	304 305 498	Summer Internship in Bioprocess Engineering **OR** Co-op Experience in Bioprocess Engineering **OR** Research Experience in Bioprocess Engineering	ES	2
BPE	310	Colloid and Interface Science *Engineering course*	ENG	3
BPE	335/336	Transport Phenomena and Laboratory	ENG	4
BPE	420	Bioseparations	ENG	3
BPE	421	Bioprocess Kinetics and Systems Engineering	ENG	3
BPE	440	Bioprocess and Systems Laboratory	ENG	3
BPE	481	Bioprocess Engineering Design	ENG	3
CLL	405	Writing for Science Professionals		2

ESF	200	Information Literacy		1
PSE	361	Engineering Thermodynamics	ENG	3
PSE	370	Principles of Mass and Energy Balances	ENG	3
PSE	371	Fluid Mechanics	ENG	3
PSE	480	Engineering Design Economics	ENG	3

Free Electives (6 credits)

Directed Electives (18 credits)

Biology or Biochemistry Electives	3-9
Chemistry or Biochemistry Electives	3-9
Engineering Electives	9-12
Any above	3

The lists of directed elective courses is available in the student handbook and from the student's advisor. Students are encouraged to select elective courses to focus one concentration area among: Biomolecular Engineering, Biochemical Engineering, Biopolymer Engineering, Bioenergy Engineering, or Environmental Engineering.

Students must take at least 9 credits of additional courses in engineering. At least one course must be from the environmental engineering courses listed in the student handbook. Additional engineering electives may be any upper-division engineering course approved by the advisor. The directed electives must total at least 18 credits.

Total minimum credits for the degree	**127**

Summer Orientation Program

All entering students (both first-year and transfer students) in the bioprocess engineering program are required to participate in the BPE Orientation Program (BPE 132). It is quite beneficial for students to attend this orientation before starting classes, as the student can learn a great deal about the curriculum and the bioprocess industry. The purpose of the program is to familiarize the student with the basic aspects of the bioprocess industry, to prepare the student for the fall courses, and to prepare the student for summer job interviews that also begin in the fall semester. The orientation program includes tours of industrial facilities and extensive discussions of the tours.

Internships, Co-ops, and Research Experiences

Bioprocess engineering students enjoy the advantage of hands-on learning in the bioprocess and allied industries through internships and co-ops. All students are required to complete a two-credit internship, co-op, or research program in the industry. Internships provide students with valuable experience, financial benefits, and two credits toward graduation. Students must submit a report and give a presentation for completion of the internship.

Students who complete a co-op in addition to the 12-week internship find the experience highly valuable because they are often able to see engineering projects through to their completion. Generally, students who have had the co-op experience are more highly recruited for permanent employment.

The co-op position, when taken in conjunction with the summer internship, consists of a work period approximately seven months in duration, either beginning in May and ending in December, or beginning in January and ending in August. Usually it takes students who complete a co-op one extra year to complete the degree requirements. Co-op students are enrolled for two credits and are required to submit a project report to fulfill the requirements for the class.

The employment interview schedule generally begins in mid-October with scheduling preference given to Syracuse Pulp and Paper Foundation member companies. Some companies schedule interviews for co-ops and summer internships at the same time they hold interviews for permanent positions. Other companies choose to hold interviews for co-ops and interns in the spring semester.

Bachelor of Science in Paper Engineering

The paper engineering program is designed to provide greater depth in chemical engineering education for students preparing for an engineering career in the pulp, paper, and allied industries as well as many other industries. Students graduating from this program are well-suited for employment as process engineers in the paper and allied chemical industry, as well as many other career opportunities. Graduates are well prepared to move into assignments in the engineering field and advance quickly to positions of responsibility in the analysis and design of processes, products and equipment.

Courses present the principles of engineering with the disciplines and examples selected especially for the pulp and paper industry. Courses include study in the basic sciences — chemistry, physics, computer science — as well as engineering topics such as statics and dynamics, mechanics, thermodynamics, transport phenomena, electricity, and design. The general education component, which is required of all ESF students, broadens the students' perspectives on global and societal issues, an important component of any education. The engineering courses cover a variety of topics that are traditional for a chemical engineering program, supplemented with courses specific to pulp and paper engineering.

Students in the program gain valuable experience through a capstone design experience in which they work on significant problems in the design and implementation of new technologies, typically in conjunction with a local recycled-paper mill. In addition, a summer internship is required of all students in which they gain valuable skills and experience in terms of technical knowledge and professional development. Both of these experiences serve to integrate the knowledge gained in their coursework with real-world work experiences commonly seen in their first positions after graduation.

Students may enter the bachelor of science program as first-year students or as transfer students at any class level with accommodations for program requirements. Students who have the associate degree in engineering science, chemical technology, general engineering, chemistry, or general science and mathematics are encouraged to apply as transfer students.

The paper engineering program is accredited by the Engineering Accreditation Commission/Accreditation Board for Engineering and Technology (EAC/ABET).

Undergraduate Program Requirements

Lower Division Required Courses (57 credits)

Courses			Credits	
APM	153	Computing Methods Professional education course	PE	3
APM	485	Differential Equations for Engineers and Scientists *Math course*	M	3
CLL	190	Writing and the Environment *Meets the requirements for general education skills and knowledge area. A complete listing of ESF or Syracuse University courses that meet the general education standards established by SUNY is listed in Undergraduate Education.*	G	3
CLL	290	Writing, Humanities, and the Environment	G	3
FCH	150/151	General Chemistry I and Laboratory *Natural science course*	G, NS	4
FCH	152/153	General Chemistry II and Laboratory	NS	4
FCH	221/222	Organic Chemistry I and Laboratory	NS	4
FCH	223/224	Organic Chemistry II and Laboratory	NS	4
FCH	380	Analytical Chemistry I	NS	3
FOR	207	Introduction to Economics	G	3
MAT	295	Calculus I	G,M	4
MAT	296	Calculus II	M	4
MAT	397	Calculus III	M	4
PHY	211/221	General Physics I and Laboratory	G,NS	4
PHY	212/222	General Physics II and Laboratory	NS	4
PSE	201	The Art and History of Papermaking *Meets the requirements for general education skills and knowledge area. A complete listing of ESF or Syracuse University courses that meet the general education standards established by SUNY is listed in Undergraduate Education.*	G	3

Electives (9 credits)

General Education Course: American History	G	3
General Education Course: Western Civilization	G	3
General Education Course: Other World Civilizations	G	3

Upper Division Required Courses (52 credits)

APM	391	Introduction to Probability and Statistics	M	3
BPE	335	Transport Phenomena *Engineering course*	ENG	3
CLL	405	Writing for Science Professionals	PE	2
ERE	440	Water Pollution Engineering	ENG	3
ESF	200	Information Literacy	PE	1
FCH	360	Physical Chemistry I	NS	3
PSE	132	Orientation Seminar: Paper Science and Engineering *Engineering science course*	ES	1
PSE	300	Introduction to Papermaking	ES	3
PSE	302	Pulp and Paper Laboratory Skills	ES	1
PSE	304	Mill Experience	ES	2
PSE	350	Pulping and Bleaching Processes	ES	3
PSE	351	Pulping and Bleaching Laboratory	ES	2
PSE	361	Engineering Thermodynamics	ENG	3
PSE	370	Principles of Mass and Energy Balances	ENG	3
PSE	371	Fluid Mechanics	ENG	3
PSE	436	Pulp and Paper Unit Operations	ENG	3
PSE	465	Paper Properties	ES	4
PSE	468	Papermaking Processes	ENG	3
PSE	480	Engineering Design Economics	ENG	3
PSE	481	Engineering Design	ENG	3

Science Directed Electives (6 credits)

Select from the following:

FCH	361	Physical Chemistry II	NS	3
PSE	466	Paper Coating And Converting	ES	3
PSE	467	Papermaking Wet End Chemistry	ES	3

Engineering Directed Electives (12 credits)

Select from the following:

ELE	231	Electrical Engineering Fundamentals I	ENG	3
ERE	223	Statics And Dynamics	ENG	4
ERE	362	Mechanics Of Materials	ENG	3
ERE	441	Air Pollution Engineering	ENG	3
PSE	477	Process Control	ENG	3

Total minimum credits for the degree 136 credits

Bachelor of Science in Paper Science

The paper science program allows those students who are more science-focused to prepare for careers in the pulp, paper, and allied industries. Students graduating from this program are well-suited for employment in many different facets of the industry, the allied chemical industry, as well as in applications of chemistry and biology. This program prepares the student for careers in the technical, managerial, or technical representative areas that extend in many directions.

The program consists mainly of chemistry, some engineering courses, and specialized courses relating to the manufacture and use of pulp and paper products. The student may choose to complete one of the options described below, with some options requiring the completion of a minor. The option electives allow the student to specialize in a subject area of interest. This program prepares the student for careers in the technical, management, or technical representative areas with opportunities to extend interests in other directions.

Students may be admitted to the paper science program as first-year students with appropriate science backgrounds from their high school or as transfers at any level with accommodations for coursework requirements. Students who have the associate degree in engineering science, chemical technology, or science and mathematics are encouraged to apply as transfer students.

Undergraduate Program Requirements

Lower Division Required Courses (50 credits)

Courses				Credits
APM	153	Computing Methods	PE	3
CLL	190	Writing and the Environment	G	3
CLL	290	Writing, Humanities and the Environment	G	3
FCH	150/151	General Chemistry I and Laboratory *Natural science course*	G, NS	4
FCH	152/153	General Chemistry II and Laboratory	NS	4
FCH	221/222	Organic Chemistry I and Laboratory	NS	4
FCH	223/224	Organic Chemistry II and Laboratory	NS	4
FCH	380	Analytical Chemistry I	NS	3
FOR	207	Introduction to Economics	G	3
MAT	295	Calculus I	G,M	4
MAT	296	Calculus II	M	4
PHY	211/221	General Physics I and Laboratory	G,NS	4
PHY	212	General Physics II and Laboratory	NS	4
PSE	201	The Art and History of Papermaking *Meets the requirements for general education skills and knowledge area. A complete listing of ESF or Syracuse University courses that meet the general education standards established by SUNY is listed in Undergraduate Education.*	G	3

Electives (9 credits)

General Education Course: American History	G	3
General Education Course: Western Civilization	G	3
General Education Course: Other World Civilizations	G	3

Upper Division Required Courses (37 credits)

CLL	405	Writing for Science Professionals		3
ESF	200	Information Literacy		1
FCH	360	Physical Chemistry I		3
FCH	361	Physical Chemistry II		3
PSE	132	Orientation Seminar: Paper Science and Engineering	ES	1
PSE	300	Introduction to Papermaking	ES	3
PSE	302	Pulp and Paper Laboratory Skills	ES	1
PSE	304	Mill Experience	ES	2
PSE	350	Pulping and Bleaching Processes	ES	3
PSE	351	Pulping and Bleaching Laboratory	ES	2
PSE	370	Principles of Mass and Energy Balances *Engineering course*	ENG	3
PSE	465	Paper Properties	ES	4
PSE	466	Paper Coating and Converting	ES	3
PSE	467	Papermaking Wet End Chemistry	ES	3
PSE	468	Papermaking Processes	ES	3

Engineering Electives (9 credits selected from the following:)

BPE	335	Transport Phenomena	ENG	3
ERE	440	Water Pollution Engineering	ENG	3
ERE	441	Air Pollution Engineering	ENG	3
PSE	361	Engineering Thermodynamics	ENG	3
PSE	371	Fluid Mechanics	ENG	3
PSE	436	Pulp and Paper Unit Operations	ENG	3
PSE	477	Process Control	ENG	3
PSE	480	Engineering Design Economics	ENG	3
PSE	481	Engineering Design	ENG	3

Technical Elective Courses (14-18 credits)

Students completing the paper science program must complete 15-18 credits of technical electives in order to satisfy the graduation requirements. Courses taken to satisfy the engineering electives above cannot also be used to satisfy the technical elective requirement. This technical elective requirement can be satisfied by completing one of the collegewide minors listed below:

- Bioprocess Science
- Computer and Information Technology
- Construction Management
- Entrepreneurship
- General Management Studies
- Marketing
- Sustainable Construction

Students not completing one of the listed minors must complete at least 15 credits of department-approved technical elective concentration coursework in the following areas:

- Biology
- Chemistry
- Pollution abatement
- Applied mathematics
- Computer modeling
- Mechanics
- Engineering design
- Materials science
- Forestry and forest management
- Biotechnology
- Wood science
- Other department-approved areas

Free Electives (6 credits)

Total minimum credits for the degree 126 credits

Summer Orientation Program

All entering students (both freshman and transfer students) in the paper science or paper engineering programs are required to participate in the PSE 132 Orientation Program. The purpose of the program is to familiarize the student with the basic aspects of the paper industry, to prepare the student for the fall courses, and to prepare the student for summer job interviews that also begin in the fall semester. The orientation program includes tours of pulp and paper mills and extensive discussions of the tours. It is quite beneficial for students to attend this orientation before starting classes, as the student can learn a great deal about the curriculum and the paper industry.

Internships and Co-ops

Paper engineering and paper science students enjoy the advantage of hands-on learning in the pulp, paper, and allied industries through paid internships and co-ops. All students are required to complete a two-credit, 12-week summer intern program in the industry (PSE 304). Internships provide students with valuable experience, financial benefits, and two credits toward graduation. Students must submit a mill report for completion of the internship.

Students who complete a co-op in addition to the 12-week internship find the experience highly valuable because they are often able to see engineering projects through to their completion. Generally, students who have had the co-op experience are recruited for permanent employment.

The co-op position is approximately seven months in duration, either beginning in May and ending in December, or beginning in January and ending in August. Usually it takes students who complete a co-op one extra year to complete degree requirements. Co-op students are enrolled for two credits and are required to submit a co-op project report in addition to the mill report required for the two-credit summer internship course.

The employment interview schedule generally begins in mid-October with scheduling preference given to Syracuse Pulp and Paper Foundation member companies. Some companies schedule interviews for co-ops and summer internships at the same time they hold interviews for permanent positions. Other companies choose to hold interviews for co-ops and interns in the spring semester.

Minors

Students are eligible to take any of the minors that are offered at ESF. The two minors most commonly completed are the general management studies minor and the computer and information technology minor, which are summarized below. See page 11 for complete description of the course requirements for these and other minors at ESF.

Bioprocess Science Minor

The bioprocess science minor is available to students in the paper science and paper engineering programs who maintain a minimum cumulative GPA of 2.8 and who desire to develop greater knowledge of bioprocess science and its related fields.

Computer and Information Technology Minor

The computer and information technology minor is available to all ESF undergraduates who want to develop greater skill in computer science and information technology applications. By understanding of the basic principles behind software development, students can more effectively use these tools in their chosen fields. The minor courses can be used to satisfy the technical electives in the paper science program.

General Management Studies Minor

The general management studies minor may be taken in conjunction with the bioprocess science, paper science, or paper engineering programs. In the paper science program, the minor courses can be used to satisfy the technical electives. Students should complete a course in microeconomics and a course in accounting prior to entering the junior year.

Paper Science Minor

The paper science minor is available to students in the bioprocess engineering program who maintain a minimum cumulative GPA of 2.8 and who desire to develop greater knowledge of paper science and its related fields.

Graduate Program

The department participates in graduate education leading to the master of professional studies, master of science, and doctor of philosophy degrees through the Division of Engineering. The option in Paper and Bioprocess Engineering allows students to

investigate a diverse range of topics in the area of pulp and paper design, process and product development, and manufacturing, as well as the production of chemicals, energy, and other products from sustainable raw material sources using both chemical and biological methods. The overall objective of the option is to educate students at the M.P.S., M.S., and Ph.D. level in the development of new processes and products that can be produced in an ecologically sound and sustainable manner.

Many research projects are carried out under the auspices of one of the premier research institutes of the world, the Empire State Paper Research Institute (ESPRI), a renowned organization supported jointly by ESF and the Empire State Paper Research Associates, an international consortium of leading industrial companies. ESPRI's research activities aim to generate new information regarding the fundamentals, science, engineering and technology of the production of products and chemicals, especially paper, from renewable resources such as wood in an ecologically sound manner. Recent work has been directed to fundamental investigations of pulping, bleaching, co-products from wood, additives, paper recycling, effluent disposal, the papermaking process, the properties of paper, reactions of wood components during mechanical and chemical treatments, novel wood component separation techniques, new biotechnologically-based pulping methods, process modeling paradigms, the structure of wood and wood fibers, evaporation, fluid dynamics, heat transfer, and chemical recovery. Pilot scale equipment in Walters Hall is often used as an integral part of these research programs.

Examples of inter- and intra-institutional collaborations include the Department of Environmental and Forest Biology and the Department of Chemistry, as well as many industrial cooperators. Cooperative studies enable access to the latest equipment in the computer field, including supercomputers. The department enjoys excellent external support in the form of graduate assistantships, fellowships, and grants from ESPRI, and other industry sources, as well as a number of government granting agencies.

Students can be accepted into the program from a variety of backgrounds. Successful students who have pursued advanced degrees in the Department of Paper and Bioprocess Engineering have had backgrounds in chemical engineering, pulp and paper engineering, civil engineering, mechanical engineering, environmental engineering, chemistry, biological engineering, biology, biotechnology, and manufacturing, among many others. Students planning to obtain graduate degrees in Paper and Bioprocess Engineering should have strong undergraduate preparation in some of following areas, depending on the particular area of study chosen: mathematics, chemistry, physics, engineering, biological sciences, and computer science. The PBE option in the environmental and resources engineering program offers areas of study in:

Chemistry of Pulping and Bleaching (M.S., Ph.D.)

Participating Faculty: AMIDON, BUJANOVIC, FRANCIS, LAI, SCOTT

- Reaction mechanisms and kinetics
- Applications of biotechnology
- Lignin and carbohydrate chemistry
- Chemicals from wood and pulping residues
- Energy from wood and pulping residues
- Chemical modification in mechanical pulping
- Catalytic and activation effects

This area of study focuses on chemical relationships and reactions basic to the manufacture and bleaching of pulp, as well as some papermaking operations. Courses in theoretical and applied chemistry are indicated, as well as specialized courses addressed directly to pulping and bleaching. Research centers on these same topics, currently stressing new and improved processes to increase energy efficiency and reduce environmental impact. These include studies on the pre-extraction of wood chips to produce acetic acid from acetyl groups, production of hydrogen and carbon monoxide from gasification of wood and pulping effluents, delignification and brightening with oxygen, hydrogen peroxide and ozone, enzyme treatment of effluent streams, mechanisms of carbohydrate reactions, and photosensitization of bleached pulps.

Colloid Chemistry and Fiber Flocculation (M.S., Ph.D.)

Participating Faculty: AMIDON, RAMARAO

- Paper sheet formation mechanisms
- Wet-end chemistry and physics
- Effects of additives in fiber networks

This study area deals with colloidal phenomena in the papermaking process, in particular the interaction among fibers, fine particles, polymeric additives, and electrolytes in stock preparation and sheet formation. Student programs feature courses in chemical engineering and colloid, polymer and physical chemistry, adding appropriate work in mathematics, statistics and papermaking processes. Research topics fall into two categories: fundamental colloidal behavior of particles and behavior of paper stock on the paper machine. In the latter, extensive use is made of pilot plant facilities in Walters Hall. Presently under investigation are adsorption-desorption behavior of polymers in papermaking, the chemistry and physics of reactive sizes on model surfaces, and principles of sheet formation.

Fiber and Paper Mechanics (M.S., Ph.D.)

Participating Faculty: ANAGNOST, BUJANOVIC, S. CHATTERJEE, DOELLE, HANNA, KYANKA, RAMARAO

- Fiber orientation and sheet properties
- Adsorption and transport of moisture in paper materials
- Mechano-sorptive phenomena

Mechanical behavior of fibers, paper and board, and other fiber networks and composites depends upon variables of material, process and structure at all levels, especially structural anisotropy. Recommended courses focus on mechanical and chemical engineering, mechanics of materials, physics, mathematics and statistics, microscopy, and wood and fiber properties. Research topics are basic in nature, designed to describe and model quantitatively the properties and behavior of fibers and fibrous structures. Current projects include studies of transient moisture sorption by paper materials, the effect of moisture on mechanical properties, influence of sheet structure on properties, use of image processing to characterize deformational behavior of paper, and determination of elastic constants of paper. Several members of the engineering departments of Syracuse University collaborate closely in this work.

Renewable Energy and Bioprocess Engineering (M.S., Ph.D.)

Participating Faculty: AMIDON, BUJANOVIC, S. CHATTERJEE, DOELLE, FRANCIS, LAI, LIU, RAMARAO, SCOTT, STIPANOVIC

- Energy from biomass and other renewable sources
- Bioseparations of lignocellulosic materials into useful components
- Bioprocessing of renewable materials
- Creation of new bioproducts using ecologically sustainable processes

This area of study encompasses both the use of renewable and sustainable resources (e.g., wood) for the production of chemicals, advanced materials, fuel, and energy, as well as the use of bioprocessing technology to produce such products. Such bio-products extend to the production of energy from renewable resources including the use of gasification, co-firing of byproducts, anerobic digestion, solar, and the production of ethanol. Courses include chemical engineering, advanced chemistry, biotechnology, and bioengineering, building on a strong base of mathematics, chemistry, and biology. Current research projects in this area include the bioseparation of xylan from hardwoods, the production of ethanol and acetic acid from wood hemicelluloses, development of separation processes for various bioproducts, gasification, enzymatic processing of lignocellulosic materials, and chemical production from sustainable resources as a replacement for non-renewable fossil fuels.

Process and Environmental Systems Engineering (M.S., M.P.S., Ph.D.)

Participating Faculty: S. CHATTERJEE, DOELLE, J.M. HASSETT, RAMARAO, SCOTT

- Behavior and control of units and systems
- Reduction of air and water pollution
- Modeling and simulation of papermaking
- Processing of fibrous wastes

Process engineering links research with development, design, operation, and optimization of manufacturing methods and equipment, seeking improvement through technological innovation consistent with environmental and resource stewardship. Principles of engineering science and mathematics are applied to analysis and dynamic modeling of units and systems, with increasing use of computers in both research and professional practice. Research here includes process dynamics and control, studies of new pulping and bleaching processes, characterization and treatment of waste streams, byproduct recovery, and computer simulation of paper processing systems. The extensive laboratories and pilot plant in Walters Hall are strongly supported by computing facilities and expertise on campus, including the Center for Computer Applications and Software Engineering (CASE) of Syracuse University. Appropriate advanced courses in engineering, mathematics and computer science are available to suit individual student interests and needs.

Pulp and Paper Technology (M.S., M.P.S., Ph.D.)

Participating Faculty: AMIDON, BUJANOVIC, DOELLE, FRANCIS, HANNA, LAI, SCOTT

- Pulping conditions and fiber properties
- Fungal and enzymatic treatments
- Chemicals and energy as byproducts
- Statistical analysis of paper structure
- Recycling of papermaking fibers

Studies in this area deal closely with processes involved in the manufacture of pulp and paper. Courses concerned with this subject are central to a student’s program, extended and enriched with selected courses in chemistry, polymers, chemical engineering, process control, applied mathematics, and computer applications. Current research projects include non-sulfur pulping, biopulping, chemicals and energy as byproducts, effects of wet pressing and press drying on sheet properties, pulping of tropical woods, and computer simulation and control of papermaking. Supporting this work is an experimental pulp and paper mill with two complete paper machines, a pressurized refiner and extensive auxiliary equipment.

Advanced (Graduate) Certificate in Bioprocessing

This bioprocessing certificate program was developed through a collaborative and interdisciplinary effort between business and academia to take advantage of this region's unique expertise and resources. Graduates of the program will support the development and manufacture of products produced through bioprocesses, such as those produced in the pharmaceutical and fermentation industries, and biorefineries.

The purpose of the certificate program is to provide:

- Graduate education in bioprocessing that leads to a documented level of competency for practice;
- A structured and documented course of study at the graduate level; and
- A means for students to improve their competitive position in the employment marketplace.

Applicants must hold a bachelor's degree from an accredited institution in engineering, science or a related area. The student must have the required prerequisite background in topics that are fundamental to bioprocessing guided from previous course-work or professional experience. Applicants must demonstrate competence in pre-calculus and quantitative problem solving, preferably with calculus. Students who are matriculated in ESF graduate degree programs are not eligible to earn the Advanced Certificate in Bioprocessing.

Application and admissions procedures, compliance with college requirements for successful graduate-level study, and the awarding of advanced certificates are administered by the dean of Instruction and Graduate Studies. Applicants should complete and submit the application form to the Office of Instruction and Graduate Studies. Upon completion of program credit hour requirements, students will file a certificate request form that identifies completed coursework and initiates actions to produce official transcripts, leading to the award of the certificate.The curriculum consists of five technical courses including a capstone professional experience/synthesis course that will provide participants with a variety of skills supporting the technical aspects of the program. The capstone course will challenge students to use the skills they learned throughout the program and apply those skills to relevant business settings. Students will complete 15 credits hours of graduate coursework with an average grade of B or better in the following required courses: ERE 501 Microbiology for Bioprocessing (3); ERE 502 Bio-separations (3); ERE 503 Bioprocess Plant Design (3); ERE 542 Bioreaction Engineering (3); and ERE 898 Professional Experience/Synthesis (3).