Energy, Environmental & Chemical Engineering

About Energy, Environmental & Chemical Engineering

Our department focuses on environmental engineering, energy systems engineering and chemical engineering. We provide integrated and multidisciplinary programs of scientific education. Our mission is accomplished by instilling a tradition of lifelong learning; offering a curriculum of fundamental education coupled with applications in advanced local areas and strengthened by our breadth in other disciplinary areas; participating in cutting-edge research with faculty and industrial partners; and providing access to state-of-the-art facilities and instrumentation. Most undergraduate students in the department will pursue the BS in Chemical Engineering degree, accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org), or the BS in Environmental Engineering degree (launched spring 2019). Other students may pursue the BS in Applied Science degree with a major in chemical engineering. The department offers a minor in environmental engineering science, and, in collaboration with other engineering departments, we co-sponsor a minor in energy engineering and a minor in nanoscale science and engineering. Graduate degrees (Master of Engineering, Master of Science and Doctor of Philosophy) in Energy, Environmental & Chemical Engineering are also offered by the department.

Chemical engineers are involved in the transfer of scientific discoveries to modern technologies and novel products that benefit society and minimize the impact on the environment. They deal with multiscale aspects of generating clean energy, producing novel and superior materials, and utilizing the biological revolution to manufacture new products. They are involved in the development and manufacture of consumer products as well as in the design, operation and control of processes in a variety of industries (e.g., petroleum, petrochemical, chemical, consumer products, food, feed, pharmaceuticals). Their broad training in basic sciences (e.g., chemistry, physics, biology, mathematics) coupled with a strong foundation in chemical engineering principles (e.g., thermodynamics, mass and energy balances, transport phenomena, kinetics, separations, reaction engineering, control, product development, process design) makes them invaluable team members and leaders in any engineering enterprise. It also prepares them well for graduate studies in biochemical, biomedical, chemical, environmental and materials engineering.

In addition, the BS in Chemical Engineering is a great starting point for pursuing a degree in business, law or medicine.

Environmental engineers apply scientific and engineering principles to assess, manage and design sustainable systems for the protection of human and ecological health. The designs and technologies that they develop provide safe and sufficient public water supplies, enable effective and efficient treatment and resource recovery from wastewater and other wastes, and control pollutant releases that protect water, soil and air quality. Environmental engineers also seek to understand the effect of technological advances on the environment and to identify opportunities to improve the environmental sustainability of new technologies. Environmental engineers have broad training in basic sciences, mathematics and computational approaches as well as an engineering foundation that includes mass and energy balances, thermodynamics, transport phenomena, and chemical, physical and biological treatment processes. The training of environmental engineers also includes natural science and environmental social science and the humanities. This training prepares environmental engineers to apply technological solutions within specific environmental and societal contexts. Environmental engineering graduates are prepared to enter professional practice and to pursue graduate study in environmental engineering and allied fields.

The curricula are planned to provide students with a strong background in basic engineering concepts while allowing students individual latitude to emphasize study in a specialized area or to obtain added breadth both within and outside of chemical or environmental engineering.

Mission Statement

The mission of the department is to teach energy, environmental and chemical engineering principles and their application in an inspiring learning environment; to prepare students for engineering careers by developing the skills of critical thinking, analysis and communication proficiency; and to instill a sense of professional ethics and societal responsibility.

Advising

The department takes pride in its mentoring of undergraduate students. Each student who declares chemical or environmental engineering as a (potential) major is assigned an academic adviser from the full-time department faculty. Typically, the same adviser follows the student’s academic progress and serves as a mentor from the first year through graduation.

Phone: 314-935-5545
Website: http://eece.wustl.edu/undergraduate/programs

Website: http://www.abet.org
Faculty

Chair and Endowed Professor

Pratim Biswas (https://engineering.wustl.edu/Profiles/Pages/Pratim-Biswas.aspx)
Lucy and Stanley Lopata Professor
PhD, California Institute of Technology
Aerosol science and engineering, air quality and pollution control, nanotechnology, environmentally benign energy production

Endowed Professors

Richard L. Axelbaum (https://engineering.wustl.edu/Profiles/Pages/Richard-Axelbaum.aspx)
Stifel and Quinette Jens Professor
PhD, University of California, Davis
Combustion, advanced energy systems, clean coal, aerosols, nanoparticle synthesis, rechargeable battery materials, thermal science

Milorad P. Dudukovic (https://engineering.wustl.edu/Profiles/Pages/Milorad-Dudukovic.aspx)
Laura and William Jens Professor
PhD, Illinois Institute of Technology
Chemical reaction engineering, multiphase reactors, visualization of multiphase flows, tracer methods, environmentally benign processing

Daniel E. Giammar (https://engineering.wustl.edu/Profiles/Pages/Daniel-Giammar.aspx)
Walter E. Browne Professor of Environmental Engineering
PhD, California Institute of Technology
Aquatic chemistry, environmental engineering, water quality, water treatment

Vijay Ramani (https://eece.wustl.edu/faculty/Pages/faculty.aspx?bio=108)
Director of Graduate Studies
Roma B. and Raymond H. Wilkoff Distinguished University Professor
PhD, University of Connecticut
Electrochemical engineering, energy conversion

Professors

Young-Shin Jun (https://engineering.wustl.edu/Profiles/Pages/Young-Shin-Jun.aspx)
PhD, Harvard University
Aquatic processes, molecular issues in chemical kinetics, environmental chemistry, surface/physical chemistry, environmental engineering, biogeochemistry, nanotechnology

Randall Martin (https://engineering.wustl.edu/news/Pages/Martin-to-join-EECE-faculty-.aspx)
PhD, Harvard University
Characterizing atmospheric composition to inform effective policies surrounding major environmental and public health challenges ranging from air quality to climate change

Palghat A. Ramachandran (https://engineering.wustl.edu/Profiles/Pages/Palghat-Ramachandran.aspx)
PhD, University of Bombay
Chemical reaction engineering, applied mathematics, process modeling, waste minimization, environmentally benign processing

Yinjie Tang (https://engineering.wustl.edu/Profiles/Pages/Yinjie-Tang.aspx)
PhD, University of Washington, Seattle
Metabolic engineering, bioremediation

Jian Wang (https://eece.wustl.edu/faculty/Pages/faculty.aspx?bio=126)
PhD, California Institute of Technology
Aerosol properties and processes, nucleation and new particle formation, aerosols in the marine environment, effects of aerosols on cloud microphysical properties and macrophysical struct

Associate Professors

Marcus Foston (https://engineering.wustl.edu/Profiles/Pages/Marcus-Foston.aspx)
PhD, Georgia Institute of Technology
Utilization of biomass resources for fuel and chemical production, renewable synthetic polymersure, and development of advanced aerosol instruments

Tae Seok Moon (https://engineering.wustl.edu/Profiles/Pages/Tae-SEok-Moon.aspx)
PhD, Massachusetts Institute of Technology
Metabolic engineering and synthetic biology

Brent Williams (https://engineering.wustl.edu/Profiles/Pages/Brent-Williams.aspx)
Raymond R. Tucker Distinguished InCEES Career Development Associate Professor
PhD, University of California, Berkeley
Aerosols, global climate issues, atmospheric sciences
Fuzhong Zhang (https://engineering.wustl.edu/Profiles/Pages/Fuzhong-Zhang.aspx)
PhD, University of Toronto
Metabolic engineering, protein engineering, synthetic and chemical biology

Assistant Professors

Peng Bai (https://engineering.wustl.edu/Profiles/Pages/Peng-Bai.aspx)
PhD, Tsinghua University, China
Develop next-generation batteries, probe the in situ electrochemical dynamics of miniature electrodes down to nanoscales, capture the heterogeneous and stochastic nature of advanced electrodes, and identify the theoretical pathways and boundaries for the rational design of materials, electrodes and batteries through physics-based mathematical modeling and simulation

Rajan Chakrabarty (https://engineering.wustl.edu/Profiles/Pages/Rajan-Chakrabarty.aspx)
PhD, University of Nevada, Reno
Characterizing the radiative properties of carbonaceous aerosols in the atmosphere; and researching gas phase aggregation of aerosols in cluster-dense conditions

Jason He (https://eece.wustl.edu/faculty/Pages/faculty.aspx?bio=198)
PhD, Washington University
Environmental biotechnology, bioenergy production, biological wastewater treatment, resource recovery, bio electrochemical systems, sustainable desalination technology, anaerobic digestion, forward osmosis and membrane bioreactors

Fangqiong Ling (https://eece.wustl.edu/faculty/Pages/faculty.aspx?bio=178)
PhD, University of Illinois at Urbana-Champaign
Microbial ecosystem analysis and modelling, process modelling, machine learning, NextGen sequencing bioinformatics, environmental microbiology, and bioreactor design

Kimberly M. Parker (https://engineering.wustl.edu/Profiles/Pages/Kimberly-Parker.aspx)
PhD, Stanford University
Investigation of environmental organic chemistry in natural and engineered systems

Elijah Thimsen (https://engineering.wustl.edu/Profiles/Pages/Elijah-Thimsen.aspx)
PhD, Washington University
Gas-phase synthesis of inorganic nanomaterials for energy applications, and novel plasma synthesis approaches

Research Assistant Professor

Benjamin Kumfer (https://engineering.wustl.edu/Profiles/Pages/Ben-Kumfer.aspx)
DSc, Washington University
Advanced coal technologies, biomass combustion, aerosol processes and health effects of combustion-generated particles

Lecturers

Janie Brennan (https://engineering.wustl.edu/Profiles/Pages/Janie-Brennan.aspx)
Director of Undergraduate Studies
PhD, Purdue University
Biomaterials, chemical engineering, engineering education

Trent Silbaugh (https://engineering.wustl.edu/Profiles/Pages/Trent-Silbaugh.aspx)
PhD, University of Washington
Chemical engineering

Avni Solanki (https://eece.wustl.edu/faculty/Pages/faculty.aspx?bio=181)
PhD, University of Florida
Wastewater, sustainable development, environmental engineering, and engineering education

Joint Faculty

Doug Allen
PhD, Purdue University
USDA Research Scientist, Danforth Plant Sciences Center
Metabolic networks of oilseed plants

Nathan Ravi
PhD, Virginia Polytechnic Institute
Cataract, ocular biomaterials

Adjunct Faculty

Robert Heider
MME, Washington University
Process control and process design

Gary Moore
MS, Missouri University of Science and Technology
Environmental management

Nicholas J. Nissing
BS, Washington University
Product development and process design

Keith Tomazi
PhD, University of Missouri-Rolla
Process development engineering

Grigoriy Yablonsky
PhD, Boreskov Institute of Catalysis
Chemical reaction engineering and heterogeneous catalysis
Research Associate
Raymond Ehrhard
BS, Missouri University of Science and Technology
Water and wastewater treatment technologies, process energy management

Senior Professor
Rudolf B. Husar
PhD, University of Minnesota
Environmental informatics, aerosol science and engineering

Majors
Please visit the following pages for information about energy, environmental and chemical engineering majors:

- Bachelor of Science in Chemical Engineering (http://bulletin.wustl.edu/undergrad/engineering/energy-environmental-chemical/bs-chemical)
- Bachelor of Science in Environmental Engineering (http://bulletin.wustl.edu/undergrad/engineering/energy-environmental-chemical/bs-environmental)
- Bachelor of Science in Applied Science (Chemical Engineering) (http://bulletin.wustl.edu/undergrad/engineering/energy-environmental-chemical/bs-applied-chemical)
- Double Majors and the Pre-Medical Program (http://bulletin.wustl.edu/undergrad/engineering/energy-environmental-chemical/double-majors-premed)

Minors
Please visit the following pages for information about the EECE minors:


Courses
Visit online course listings to view semester offerings for E44 EECE (https://courses.wustl.edu/CourseInfo.aspx?sch=E&dept=E44&crslvl=1:5).

E44 EECE 100 Independent Study
Independent investigation on topic of special interest. Interested students are encouraged to approach and engage faculty to develop a topic of interest. A form declaring the agreement must be filed in the departmental office. Petitions are generally considered in the semester preceding the independent study experience. Prerequisite: freshman standing. Credit variable, maximum 3 units.

E44 EECE 101 Introduction to Energy, Environmental and Chemical Engineering
Key technical issues that face our society and some of the emerging technologies that hold promise for the future are examined and discussed. Relationship to chemical engineering principles is emphasized. Credit 3 units. EN: TU

E44 EECE 103 Topics in Energy, Environmental and Chemical Engineering
Key technical issues that face our society and some of the emerging technologies that hold promise for the future are examined and discussed. This course provides a broader context for content delivered in concurrent core chemical and environmental engineering courses. Credit 1 unit.

E44 EECE 112 Earth's Future: Causes and Consequences of Global Climate Change
Earth's Future: Causes and Consequences of Global Climate Change examines 1) the physical basis for climate change; 2) how climates are changing and how we know and assess that climates are changing; and 3) the effects of climate change on natural and human systems. The course is team-taught and will involve participation by scholars across the university with expertise in specific subjects. This is a broad, introductory course for first year students and presumes no special subject matter knowledge on the part of the student. Same as I50 INTER D 101 Credit 3 units. A&S: FYBB A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

E44 EECE 200 Independent Study
Independent investigation on topic of special interest. Interested students are encouraged to approach and engage faculty to develop a topic of interest. A form declaring the agreement must be filed in the departmental office. Petitions are generally considered in the semester preceding the independent study experience. Prerequisite: sophomore standing. Credit variable, maximum 3 units.

E44 EECE 202 Computational Modeling in Energy, Environmental and Chemical Engineering
Computational tools to solve engineering, design and scientific problems encountered in thermodynamics, transport phenomena, separation processes and reaction kinetics. Introduction to programming skills in MATLAB and use of various MATLAB toolboxes. Theory and application of numerical methods for solution of common problems, including methods for root-finding/optimization, curve fitting (regression, interpolation, and spline), integration, differentiation, and ordinary differential equations and boundary value problems. Illustrative application examples. Prerequisites: Math 233 and Math 217, or permission of instructor. Credit 3 units. EN: TU
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
<th>Prerequisites</th>
<th>Credit Units</th>
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<tbody>
<tr>
<td>E44 EECE 204</td>
<td>Thermodynamics II in EECE</td>
<td>Molecular motions, kinetic theory of gases, kinetic theory of dense phases, chemical kinetics. Prerequisite: EECE 203.</td>
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<td>3 units. EN: TU</td>
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<tr>
<td>E44 EECE 205</td>
<td>Process Analysis and Thermodynamics</td>
<td>This course is an introduction to the use of mathematics and methods of engineering in the analysis of chemical and physical processes. It will address the use of balances (mass, energy, entropy) to describe processes with and without chemical reaction in both transient and steady state conditions as well as classical thermodynamics focused on processes, first and second laws, and properties of pure substances. Prerequisites: Chem 112A and Math 233. Corequisite: Math 217.</td>
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<td>3 units. EN: TU</td>
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<tr>
<td>E44 EECE 210</td>
<td>Introduction to Environmental Engineering</td>
<td>The objective of this course is to introduce students to the field of environmental engineering. The course will emphasize basic principles of mass and energy conservation which govern physical, chemical and biological processes. Applications include the estimation of contaminant concentrations and the design of environmental controls. Prerequisites: Chem 112A and Math 233.</td>
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<td>3 units. EN: TU</td>
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<tr>
<td>E44 EECE 300</td>
<td>Independent Study</td>
<td>Independent investigation on topic of special interest. Interested students are encouraged to approach and engage faculty to develop a topic of interest. A form declaring the agreement must be filed in the departmental office. Petitions are generally considered in the semester preceding the independent study experience. Prerequisite: junior standing.</td>
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<td>Credit variable, maximum 3 units.</td>
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<tr>
<td>E44 EECE 301</td>
<td>Transport Phenomena I: Basics and Fluid Mechanics</td>
<td>Engineering principles involved in the exchange of heat and matter in chemical processes. Laws governing the flow of liquids and gases in laboratory and plant equipment. Corequisite: EECE 202; Prerequisites: EECE 203, Math 217, ESE 318, or permission of instructor.</td>
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<td>3 units. EN: BME T, TU</td>
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<tr>
<td>E44 EECE 302</td>
<td>Transport Phenomena II: Mass Transfer</td>
<td>Engineering principles involved in the exchange of heat and matter in chemical processes. Laws governing the flow of liquids and gases in laboratory and plant equipment. Prerequisite: EECE 301.</td>
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<td>3 units. EN: BME T, TU</td>
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<tr>
<td>E44 EECE 304</td>
<td>Mass Transfer Operations</td>
<td>Stagewise and continuous mass transfer operations, including distillation, gas absorption, humidification, leaching, liquid extraction, and membrane separations. Prerequisites: Math 217, EECE 201 and EECE 203.</td>
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<td>3 units. EN: BME T, TU</td>
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<tr>
<td>E44 EECE 305</td>
<td>Materials Science</td>
<td>Introduces the chemistry and physics of engineering materials. Emphasis on atomic and molecular interpretation of physical and chemical properties, the relationships between physical and chemical properties, and performance of an engineering material. Prerequisite: Math 217, Chem 111A.</td>
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<td>3 units. EN: BME T, TU</td>
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<tr>
<td>E44 EECE 309</td>
<td>Environmental Engineering Fate and Transport</td>
<td>The objective of this course is to introduce students to the fundamental processes that control contaminant fate and transport in the natural and built environment. The course will highlight mass transport and transformation in surface water, soil and groundwater, and atmosphere. Students will be introduced to environmental transport modeling software to solve applied problems. Prerequisites: EECE 210 and EECE 301.</td>
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<td>3 units. EN: TU</td>
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<tr>
<td>E44 EECE 314</td>
<td>Air Quality Engineering with Lab</td>
<td>Introduction to air quality and pollution control. Pollutant emissions, atmospheric chemistry, and fate. Air pollution meteorology and atmospheric dispersion. Application of chemistry, thermodynamics, and fluid mechanics in the selection and design of air pollution control equipment. Labs to measure air quality and demonstrate control principles.</td>
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<td>4 units. EN: TU</td>
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<td>E44 EECE 400</td>
<td>Independent Study</td>
<td>Independent investigation on topic of special interest. Interested students are encouraged to approach and engage faculty to develop a topic of interest. A form declaring the agreement must be filed in the departmental office. Petitions are generally considered in the semester preceding the independent study experience. Prerequisite: senior standing.</td>
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<td>Credit variable, maximum 6 units.</td>
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<td>E44 EECE 401</td>
<td>Chemical Process Dynamics and Control</td>
<td>A state-of-the-art industrial virtual plant is used for the development of dynamic simulations, selection of instrumentation, statistical analysis of variability, and implementation of process control to improve process operation and efficiency. Prerequisite: Math 217 and EECE 201.</td>
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<td>3 units. EN: BME T, TU</td>
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</table>
E44 EECE 402 ChE Capstone
Application of engineering science and design, fundamentals of process and product development, computational techniques and economic principles to design of chemical and biological processes and procedures. A design project and/or an AICHE national design contest is included. Prerequisites: EECE 203, 301, 302, 304 and 403. Credit 3 units. EN: BME T, TU

E44 EECE 403 Chemical Reaction Engineering
Introduction to chemical reaction engineering principles and applications in process and product development. Evaluation of reaction rates from mechanisms and experimental data, quantification of pertinent transport effects and application to reactor and product design. Prerequisites: EECE 201, 203, 204, 301. Credit 3 units. EN: BME T, TU

E44 EECE 405 Unit Operations Laboratory
Laboratory projects focused on the application of chemical engineering principles (transport, thermodynamics, separations, etc.). Student teams design multi-week experiments utilizing unit operations equipment to solve realistic engineering problems. Includes analysis of safety and instrumentation. One laboratory period each week with supplemental lecture sessions. Emphasis on independent learning, teamwork, and technical communication skills. Prerequisites: EECE 301, 304; Corequisite: EECE 403. Credit 4 units. EN: TU

E44 EECE 407 Environmental Biotechnology
This course aims to provide students with a background in current environmental biotechnology and to stimulate ideas about future potential new technologies. Students will gain qualitative and quantitative skills related to bioreactor designs in environmental applications (e.g., activated sludge, anaerobic digestion, membrane bioreactors). Special focus will be placed on the application of mathematical models that are currently widely used in wastewater engineering, such as the International Water Association models. Hands-on experience with biological water treatment process modelling will be provided. Finally, students will be encouraged to explore links between environmental biotechnologies and a “one health” approach to public health. Prerequisites: Biol 2960 or EECE 306, ESE 326, EECE 204, EECE 210. Credit 3 units. EN: TU

E44 EECE 411 International Experience in EECE
This course will provide undergraduate students with an international experience related to energy, environmental and/or chemical engineering. The country visited will vary from year to year, with one or more EECE faculty members developing the program in collaboration with McDonnell Global Energy and Environment Partnership (MAGEEP) universities. Example activities include conducting field or laboratory research, attending short courses taught by MAGEEP university faculty members, and visiting attractions relevant to the course focus (e.g., industrial facilities). Students will also gain an understanding of the local culture and history of the country visited. Course content will include a seminar series in the spring semester prior to the international experience, a two- to three-week visit to the location of study, and a follow-up student project and presentations during the fall semester that draw upon the experience. Students will enroll in EECE 411 for the fall semester following the trip. Credit 3 units. EN: BME T, TU

E44 EECE 412 Sustainability Exchange: Community and University Practicums
The Sustainability Exchange will bring together students working in transdisciplinary teams to tackle real-world energy, environmental, and sustainability problems through an experiential form of education. Students will participate in projects with clients and partners on- or off-campus, developed with and guided by faculty advisers drawn from across the university, with the intention of delivering an applicable end-product that explores “wicked” problems requiring innovative methods and solutions. These projects matter to the client or partner. The team-based project will be complemented by a seminar that will explore the field of design and design thinking through problem solving strategies and methodologies drawn from a wide range of creative practices, including design, engineering and science, as well as contemporary topics in energy, environment and sustainability. Students will draw on these topics to influence their projects. This course is open to all undergraduate juniors and seniors. An application is required; students will be accepted off the wait list following the application process. Same as I50 INTER D 405 Credit 3 units. A&S IQ: SSC Arch: SSC Art: CPSC, SSC EN: S

E44 EECE 413 Energy Conversion and Storage
This course takes a thermodynamics perspective to analyzing electricity production and distribution systems, which are imperative to modern society. The course contains a hands-on laboratory component. Traditional and advanced heat engine cycles will be discussed. Opportunities and challenges with renewable energy technologies will be covered. Essential to the widespread adoption of renewable electricity sources and also to increasing energy efficiency are smart grid and smart building technologies. The goal is to give the student a quantitative overview while focusing in on the details of a few important technological examples. Prerequisites: E44 203 and E44 301. Credit 3 units. EN: BME T, TU

E44 EECE 414 New Product and Process Development
An overview of product development, innovative solutions to technical problems, designed experimentation, evaluation of abstract data, product design, and the basics of intellectual property. Prerequisites: junior standing and Chem 251, EECE 203 or permission of the instructor. Credit 3 units. EN: TU

E44 EECE 423 Senior Thesis
Research project to be selected by the student with the permission and recommendation of a faculty supervisor and the approval of the department chair. At conclusion of project, student prepares a report in the form of a senior thesis. Credit variable, maximum 6 units.

E44 EECE 424 Digital Process Control Laboratory
Applications of digital control principles to laboratory experiments supported by a networked distributed control system. Lecture material reviews background of real-time programming, data acquisition, process dynamics, and process control. Exercises in data acquisition and feedback control design using simple and
advanced control strategies. Experiments in flow, liquid level, temperature, and pressure control. Term project. Prerequisite: ESE 441 or EECE 401 or equivalent. Credit 3 units. EN: BME T, TU

E44 EECE 425 Environmental Engineering Laboratory
Laboratory experiments to illustrate the application of engineering fundamentals to environmental systems. Applications of experimental design and data analysis principles. Introduction to relevant analytical instrumentation and laboratory techniques. Laboratory work supported by theoretical analysis and modeling as appropriate. Prerequisite: consent of instructor. Credit 3 units. EN: BME T, TU

E44 EECE 426 ChE Honors Design Project for AIChE
Student Contest Problem
Application of engineering science and design, fundamentals of process and product development, computational techniques and economic principles to design of chemical and biological processes and procedures in solving the AIChE national student contest problem. Up to two single and up to two group (2-3 per group) solutions may be chosen for national competition. Corequisites: EECE 402, 403. Prerequisites: EECE 203, 301, 302, 304 Credit 1 unit. EN: TU

E44 EECE 500 Independent Study
Independent investigation on topic of special interest. Interested students are encouraged to approach and engage faculty to develop a topic of interest. A form declaring the agreement must be filed in the departmental office. Petitions are generally considered in the semester preceding the independent study experience. Prerequisite: graduate-level standing. Credit variable, maximum 9 units.

E44 EECE 501 Transport Phenomena in EECE
The aim of the course is for students to develop skills in applying principles of momentum, heat and mass transport in a unified manner to problems encountered in the areas of energy, environmental and chemical processes. A systems approach will be followed so that the general principles can be grasped, and the skills needed to develop mathematical models of seemingly different processes will be emphasized. This provides the students with general tools that they can apply later in their chosen field of research. Credit 3 units.

E44 EECE 502 Advanced Thermodynamics in EECE
The objective of this course is to understand classical thermodynamics at a deeper level than is reached during typical undergraduate work. Emphasis will be placed on solving problems relevant to chemical engineering materials science. Prerequisite: E44 203 or equivalent. Credit 3 units.

E44 EECE 503 Mathematical Methods in EECE
The course will introduce students to mathematical principles essential for graduate study in any engineering discipline. Applied mathematical concepts will be demonstrated by applications to various areas in energy, environmental, biomedical, chemical, mechanical, aerospace, electrical and civil engineering.

Credit 3 units.

E44 EECE 504 Aerosol Science and Technology

E44 EECE 505 Aquatic Chemistry
Aquatic chemistry governs aspects of the biogeochemical cycling of trace metals and nutrients, contaminant fate and transport, and the performance of water and wastewater treatment processes. This course examines chemical reactions relevant to natural and engineered aquatic systems. A quantitative approach emphasizes the solution of chemical equilibrium and kinetics problems. Topics covered include chemical equilibrium and kinetics, acid-base equilibria and alkalinity, dissolution and precipitation of solids, complexation of metals, oxidation-reduction processes, and reactions on solid surfaces. A primary objective of the course is to be able to formulate and solve chemical equilibrium problems for complex environmental systems. In addition to solving problems manually to develop chemical intuition regarding aquatic systems, software applications for solving chemical equilibrium problems are also introduced. Prerequisite: senior or graduate-level standing. Credit 3 units. EN: BME T, TU

E44 EECE 506 Bioprocess Engineering I: Fundamentals & Applications
The course covers the fundamentals and provides the basic knowledge needed to understand and analyze processes in biotechnology in order to design, develop and operate them efficiently and economically. This knowledge is applied to understand various applications and bioprocesses, such as formation of desirable bio and chemical materials and products, production of bioenergy, food processing and waste treatment. The main objective of the course is to introduce the essential concepts and applications of bioprocessing to students of diverse backgrounds. An additional project is required to obtain graduate credit. Prerequisites: L41 Biol 2960 or equivalent or permission of instructor. Credit 3 units. EN: BME T, TU

E44 EECE 507 Kinetics and Reaction Engineering Principles
This course is aimed at a modern multiscale treatment of kinetics of chemical and biochemical reactions and the application of these fundamentals to analyze and design reactors. Application of reaction engineering principles in areas related to energy generation, pollution prevention, chemical and biochemical processes will be studied and illustrated with case studies and computer models. Description of the role of mass and heat transport in reacting systems is also provided, with numerous examples. Credit 3 units.

E44 EECE 508 Research Rotation
First-year doctoral students in EECE should undertake Research Rotation as a requirement prior to choosing a permanent
research adviser. The rotation will require the student to work under the guidance of a faculty member.

**E44 EECE 509 Seminar in Energy, Environmental, and Chemical Engineering**
All graduate students in EECE should attend the Departmental Seminar Series to gain exposure to various diverse fields of research. Students are also expected to participate in journal clubs and other discussion formats to discuss topical research areas. This course is required of all graduate students every semester of residency in the program.
Credit 1 unit.

**E44 EECE 510 Advanced Topics in Aerosol Science & Engineering**
This course will be focused on the discussion of advanced topics in aerosol science and engineering and their applications in a variety of fields, including materials science, chemical engineering, mechanical engineering, and environmental engineering. Prerequisite: EECE 504.
Credit 3 units. EN: BME T, TU

**E44 EECE 512 Combustion Phenomena**
This course provides an introduction to fundamental aspects of combustion phenomena, including relevant thermochemistry, fluid mechanics, and transport processes as well as the interactions among them. Emphasis is on elucidation of physico-chemical processes, problem formulation and analytic techniques. Topics covered include non-premixed and premixed flames, deflagrations and detonations, particle combustion, flame extinction, flame synthesis, pollutant formation, and methods of remediation. Contemporary topics associated with combustion are discussed throughout. Prerequisites: graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

**E44 EECE 514 Atmospheric Science and Climate**
This course will cover current research topics in atmospheric chemistry and climate change. Topics include atmospheric composition, chemistry, transport, dynamics, radiation, greenhouse gases, natural and anthropogenic primary pollution sources and secondary aerosol production, and measurement techniques. Focus will be placed on how our atmosphere and climate are altered in a world of changing energy production and land use. Prerequisites: Chemistry 112A, Physics 198, and junior or higher standing.
Credit 3 units. EN: BME T, TU

**E44 EECE 516 Measurement Techniques for Particle Characterization**
The purpose of this course is to introduce students to the principles and techniques of particle measurement and characterization. Practical applications of particle technology include air pollution measurement, clean manufacturing of semiconductors, air filtration, indoor air quality, particulate emission from combustion sources and so on. The course will focus on the following: (1) integral moment measurement techniques; (2) particle sizing and size distribution measuring techniques; and (3) particle composition measurement techniques. Related issues such as particle sampling and transportation, instrument calibration, and particle standards will also be covered.
Credit 3 units. EN: BME T, TU

**E44 EECE 531 Environmental Organic Chemistry**
Fundamental, physical-chemical examination of organic molecules (focused on anthropogenic pollutants) in aquatic (environmental) systems. Students learn to calculate and predict chemical properties that are influencing the partitioning of organic chemicals within air, water, sediments and biological systems. This knowledge will be based on understanding intermolecular interactions and thermodynamic principles. Mechanisms of important thermochemical, hydrolytic, redox, and biochemical transformation reactions are also investigated, leading to the development of techniques (such as structure-reactivity relationships) for assessing environmental fate or human exposure potential. Prerequisites: EECE 210, Chem 112A, Chem 261.
Credit 3 units. EN: BME T, TU

**E44 EECE 533 Physical and Chemical Processes for Water Treatment**
Water treatment is examined from the perspective of the physical and chemical unit processes used in treatment. The theory and fundamental principles of treatment processes are covered and are followed by the operation of treatment processes. Processes covered include gas transfer, adsorption, precipitation, oxidation-reduction, flocculation, sedimentation, filtration, and membrane processes. Prerequisites: EECE 201; EECE 204; EECE 210 or equivalents
Credit 3 units. EN: BME T, TU

**E44 EECE 534 Environmental Nanochemistry**
This course involves the study of nanochemistry at various environmental interfaces, focusing on colloidal, nanoparticle, and surface reactions. The course also (1) examines the thermodynamics and kinetics of nanoscale reactions at solid-water interfaces in the presence of inorganic or organic compounds and microorganisms; (2) investigates how nanoscale interfacial reactions affect the fate and transport of contaminants; (3) introduces multidisciplinary techniques for obtaining fundamental information about the structure and reactivity of nanoparticles and thin films and the speciation or chemical form of environmental pollutants at the molecular scale; and (4) explores connections between environmental nanochemistry and environmental kinetic analysis at larger scales. This course will help students attain a better understanding of the relationship between nanoscience/technology and the environment, specifically how nanoscience could potentially lead to better water treatments, more effective contaminated-site remediation, or new energy alternatives.
Credit 3 units. EN: BME T, TU

**E44 EECE 551 Metabolic Engineering and Synthetic Biology**
Synthetic Biology is a transformative view of biology from “observation approach” to “synthesis approach.” It is new “engineering” discipline and aims to make the engineering of new biological function predictable, safe, and quick. It will pave a wide range of applications to transform our views on production of sustainable energy and renewable chemicals, environmental problems, and human disease treatments. The field intersects with Metabolic Engineering in areas such as the design of novel pathways and genetic circuits for product generation and toxic chemical degradation. In this course, the field and its basis are introduced. First, relevant topics in biology, chemistry, physics, and engineering are covered. Second, students will participate in brainstorming and discussion on new biology-based systems.
Last, students will design and present new synthetic biology systems to solve real-world problems. No prerequisite. Both undergrad and graduate students can take this course. Credit 3 units. EN: BME T, TU

E44 EECE 552 Biomass Energy Systems and Engineering
This course offers background in the organic chemistry, biology and thermodynamics related to understanding the conversion of biomass. In addition includes relevant topics relating to biomass feedstock origin, harvest, transportation, storage, processing and pretreatment along with matters concerning thermo- and bio-chemical conversion technologies required to produce fuels, energy, chemicals, and materials. Also, various issues with respect to biomass characterization, economics and environmental impact will be discussed. The main objective of the course is to introduce concepts central to a large-scale integrated biomass bioconversion system. Credit 3 units. EN: BME T, TU

E44 EECE 554 Molecular Biochemical Engineering
This course is set for junior-level graduate students to bridge the gap between biochemical engineering theory and academic research in bioengineering. It will cover common molecular biotechnologies (molecular biology, microbiology, recombinant DNA technology, protein expression, etc.), biochemical models (enzyme catalysis, microbial growth, bioreactor, etc.) and bioengineering methodologies (protein engineering, expression control systems, etc.). These theories and technologies will be introduced in a manner closely related to daily academic research or biochemical industry. Areas of application include biofuel and chemical production, drug discovery and biosynthesis, bioremediation, and environmental applications. This course also contains a lab section (~20-30%) that requires students to apply the knowledge learned to design experiments, to learn basic experimental skills, and to solve current research problems. Prerequisites: EECE 101, Bio 2960, Bio 4810. Credit 3 units. EN: BME T, TU

E44 EECE 572 Advanced Transport Phenomena
Analytical tools in transport phenomena: Scaling, perturbation and stability analysis. Numerical computations of common transport problem with MATLAB tools. Low Reynolds number flows and applications to microhydrodynamics. Turbulent flow analysis and review of recent advances in numerical modeling of turbulent flows. Convective heat and mass transfer in laminar and turbulent flow systems. Introduction to two phase flow and multiphase reactors. Pressure-driven transport and transport in membranes, electrochemical systems, double layer effects and flow in microfluid devices. Prerequisites: EECE 501 (Transport phenomena) or equivalent senior level courses in fluid mechanics and heat transfer. Credit 3 units. EN: BME T, TU

E44 EECE 574 Electrochemical Engineering
This course will teach the fundamentals of electrochemistry and the application of the same for analyzing various electrochemical energy sources/devices. The theoretical frameworks of current-potential distributions, electrode kinetics, porous electrode and concentrated solution theory will be presented in the context of modeling, simulation and analysis of electrochemical systems. Applications to batteries, fuel cells, capacitors, and copper deposition will be explored. Pre-/corequisites: EECE 501-502 (or equivalent) or permission of instructor. Credit 3 units.