CHEMICAL & MATERIALS ENGINEERING

Mission

The New Mexico State University Chemical & Materials Engineering (CHME) Department strives to prepare Chemical Engineering Bachelor of Science graduates to successfully and safely practice the chemical engineering profession, to engage in life-long personal and professional development, and to contribute to the betterment of their community and society. The undergraduate chemical engineering program of the CHME Department is accredited by the Engineering Accreditation Commission of ABET, Inc. Completion of an ABET accredited degree is required for licensure in New Mexico.

Undergraduate Program Information

Chemical engineers solve problems by combining the fundamentals of physical sciences (chemistry and physics) and life sciences (biology, microbiology, biochemistry) with the principles of engineering analysis, mathematics, and economics. The curriculum of study leading to the BSCHE continuously builds on prerequisite knowledge. The capstone course requires completion of a series of seven prerequisite courses, each having its own prerequisites. In this manner, the BSCHE produces graduates with highly developed problem-solving capabilities, strong communication and interpersonal skills, and an ability to seek out and assimilate knowledge beyond the classroom. Graduates apply these competencies to solve problems across a wide range of industries in the private and public sectors.

The work of a chemical engineer typically leads to the development of processes that convert raw materials (chemicals) into more useful or valuable products. Chemical engineers are pioneers of modern materials and associated processes that are essential to the fields of:

- nanotechnology;
- fuel cells;
- computer chip manufacture;
- environmental restoration and pollution prevention;
- biomedical, biotechnology and bioengineering;
- pharmaceutical manufacturing;
- food production;
- transportation (automotive and aerospace);
- advanced materials;
- petrochemical and refining;
- chemical synthesis and production; and
- power & energy (including the nuclear industry).

Graduates are also well-prepared to continue the study of law, medicine or advanced engineering topics at the graduate level.

Undergraduate Program Educational Objectives

The Chemical & Materials Engineering Department at New Mexico State University strives to produce undergraduates who will:

1. apply their problem-solving and communication skills to chemical engineering industries, government research labs, academia, and related fields;
2. implement safety practices in their work;
3. be on the path to leadership; and
4. build new skills sets through continuing education and professional development.

These Program Educational Objectives (PEOs), which are modified based on input from our constituencies, are consistent with the missions of NMSU, the College of Engineering and the Department of Chemical & Materials Engineering.

Graduate Program Information

The Department of Chemical and Materials Engineering offers graduate study leading to the M.E., M.S. and Ph.D. degrees with an emphasis in chemical engineering. Admission to the program is in accord with the general regulations of the Graduate School. The Graduate Record Examination (GRE) General Test is required for applicants for the M.S. and Ph.D. programs. All graduate students are required to pass all graduate engineering courses with a minimum grade of B-.

All M.S. and Ph.D. graduate students must select a thesis or dissertation advisor by the end of their first semester in the chemical engineering graduate program. In addition, doctoral students must complete their Program of Study and Committee form by the end of their first semester. Masters students must complete their Program of Study form by the end of their first semester. Thesis/dissertation may be pursued in absentia at various industrial sites by special arrangement.

Graduate teaching and research assistantships, fellowships and traineeships are available. For consideration for financial assistance, completed applicants must be received by March 1. All support is contingent upon availability, eligibility and satisfactory progress toward the degree.

Each student admitted to the CHME grad program who has an undergraduate degree in a discipline other than chemical engineering must schedule a meeting with the CHME Department Head to identify undergraduate course deficiencies that the student must take to obtain a graduate degree in chemical engineering.

Graduate Program Educational Objectives

Chemical & Materials Engineering graduate students must:

1. demonstrate skills in the (1) design of experiments or simulations, (2) collection of experimental/simulated data, (3) development of appropriate models, and (4) make appropriate use of those models;
2. complete an independent research project, resulting in at least a thesis/dissertation and peer-reviewed journal article(s);
3. defend original research in front of a panel of peers and experts;
4. be knowledgeable of the contemporary issues that are relevant to their chosen area of research.

Degrees for the Department

Bachelor Degree(s)

- Chemical Engineering - Bachelor of Science in Chemical Engineering (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/chemical-engineering-bachelor-science-chemical-engineering/)

Master Degree(s)

- Chemical Engineering - Master of Engineering in Chemical Engineering (https://catalogs.nmsu.edu/nmsu/graduate-school/chemical-engineering-master-engineering-chemical-engineering/)
- Chemical Engineering - Master of Engineering in Chemical Engineering (Online) (https://catalogs.nmsu.edu/global/nmsu-global/chemical-engineering-master-engineering-chemical-engineering-online/)
- Chemical Engineering - Master of Science in Chemical Engineering (https://catalogs.nmsu.edu/nmsu/graduate-school/chemical-engineering-master-science-chemical-engineering/)

Doctoral Degree(s)

- Engineering (Chemical Engineering) - Doctor of Philosophy (https://catalogs.nmsu.edu/nmsu/graduate-school/engineering-chemical-engineering-doctor-philosophy/)

Minors for the Department

- Biomedical Engineering - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/biomedical-engineering-undergraduate-minor/)
- Brewery Engineering- Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/brewery-engineering-undergraduate-minor/)
- Computational Engineering- Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/computational-engineering-undergraduate-minor/)
- Materials Engineering - Graduate Minor (https://catalogs.nmsu.edu/nmsu/graduate-school/materials-engineering-graduate-minor/)
- Materials Engineering - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/materials-engineering-undergraduate-minor/)
- Nuclear Chemical Engineering - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/nuclear-chemical-engineering-undergraduate-minor/)
- Pre-Law in Intellectual Property - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/pre-law-in-intellectual-property-undergraduate-minor/)
- Pre-Medicine Studies- Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/chemical-materials-engineering/pre-medicine-studies-undergraduate-minor/)

Department Head: Joseph H. Holles[1]

Associate Department Head: Paul K. Andersen

Professors Holles[1], Houston, Luo, ***Associate Professors*** Andersen, Brewer, Manz, Martinez-Monteagudo, Zhou ***Assistant Professors*** Gallegos, Li ***Emeritus Professors*** Bhada, Ghassemi, Mitchell, Rockstraw[1] ***Professors of Practice*** Taylor

Research Interests:

P.K. Andersen (Ph.D., University of California, Berkeley) physicochemical hydrodynamics, nuclear chemical engineering, modeling and simulation, education and training*; C.E. Brewer* (Ph.D., Iowa State) biomass thermochemical processing, sustainable agriculture, biorenewable resources, brewery engineering; *A.A. Gallegos* (Ph.D., University of California Riverside) computational modeling of soft matter, molecular thermodynamics, polymer physics; *J.H. Holles[1]* (Ph.D., Virginia) heterogeneous catalysis, structure/property relationships in catalysis, pseudomorphic overlayer bimetallic catalysts, research preparation for undergraduate and graduate students*; J. P. Houston* (Ph.D., Texas A&M) biomedical engineering, biophotonics, flow cytometry*; H. Li* (Ph.D., Washington State) heterogeneous catalysis, sustainable technologies, waste valorization;*H. Luo* (Ph.D., Tulane) nanostructured materials, thin films, photovoltaics, batteries, electrocatalysts, photocatalysts*; T.A. Manz* (Ph.D., Purdue) quantum chemistry simulations of materials, catalysis, and space physics*; S. Martinez-Monteagudo* (Ph.D., University of Alberta, Canada) food engineering, valorization of byproduct streams, synthesis of sweeteners, and green extraction methods*; S. Taylor* (Ph.D., Clemson) synthesis and characterization of materials, brewing, food processing*; M. Zhou* (Ph.D., New Mexico State) hydrogen production, CO_2 reduction, fuel cell and solar cell.

[1] Registered Professional Engineer

Chemical Engineering Courses

CHME 101. Introduction to Chemical Engineering Calculations
2 Credits (2)
Introduction to the discipline of chemical engineering, including: an overview of the curriculum; career opportunities; units and conversions; process variables; basic data treatments; and computing techniques including use of spreadsheets.
Prerequisite/Corequisite: MATH 1220G, or MATH 1250G, or MATH 1511G.
Learning Outcomes

1. Describe career opportunities available to holders of a BSCHE degree.
2. Find and use learning and advising resources within CHME and Engineering.
3. Create a course registration plan for future semesters that meets the degree and prerequisite requirements for the BSCHE in the timeliest manner.
4. Diagram a process with unit operations and material and energy flows.
5. Perform unit analysis and unit conversions accurately and efficiently.
6. Validate calculated results using estimation techniques.
7. Apply the concept of significant figures to numerical answers.
8. Identify and describe process variable measurements using engineering vocabulary.
9. Express and convert concentrations using mass, mole, and volume bases. 1
10. Convert between absolute and relative pressure and temperature scales. 1
11. Perform calculations in Excel using built-in and custom functions. 1
12. Generate 2-D plots of data and functions in Excel. 1
13. Perform a regression of data to a mathematical model.

CHME 102. Material Balances
2 Credits (2)
Perform material balances in single- and multi-phase, reacting and non-reacting systems under isothermal conditions.
Prerequisite: MATH 1220G, or MATH 1250G, or MATH 1511G.
Learning Outcomes

1. Analyze data using trendlines. Linearize when necessary.
2. Use unit conversions when solving problems.
3. Turn a verbal or written problem statement into a diagram and a mathematical form.

4. Write and solve material balances on single and multi-unit processes, for both nonreactive and reactive processes.
5. Identify what phase a substance is in and then be able to use the correct equations to relate volume to mass and moles.
6. Use Raoult's and Henry's law when solving mass balances.

CHME 201. Energy Balances & Basic Thermodynamics
3 Credits (3)
Chemical Engineering energy balances; combined energy and material balances including those with chemical reaction, purge and recycle; thermochemistry; application to unit operations. Introduction to the first and second laws of thermodynamics and their applications. May be repeated up to 3 credits.
Prerequisite: CHME 102 and MATH 1250G or MATH 1511G.
Prerequisite/Corequisite: CHEM 1216 or CHEM 1215G.
Learning Outcomes
1. Correctly implement unit conversions (outcome (a) an ability to apply knowledge of mathematics, science, and engineering).
2. Analyze and solve elementary material balances on single and multi-unit process, for both nonreactive and reactive processes.
3. Apply the first law of thermodynamics to batch and flow processes.
4. Locate thermophysical property data in the literature and estimate properties when data are not available.
5. Conduct combined material and energy balances around continuous multi-unit processes with and without chemical reaction.
6. Perform process calculations using psychrometric charts, enthalpy concentration diagrams and steam tables.
7. Derive and solve differential equations for transient heat and material balances on dynamic systems.
8. Determine individual learning style and describe how learners of that style can help themselves.
9. Use modern engineering tools (example, Excel) to solve material and energy balance problems.

CHME 303. Chemical Engineering Thermodynamics
4 Credits (4)
Applications of the First Law and Second Law to chemical process systems, especially phase and chemical equilibria and the behavior of real fluids. Development of fundamental thermodynamic property relations and complete energy and entropy balances. Modeling of physical properties for use in energy and entropy balances, heat and mass transfer, separations, reactor design, and process control.
Prerequisite: CHME 201.
Prerequisite/Corequisite: MATH 1511G.
Learning Outcomes
1. Use an engineering approach to solve a problem (identify scope, create diagram, determine knowns and unknowns, apply appropriate equations, calculate solutions and evaluate reasonableness of the solution)
2. Solve engineering problems using material, energy and entropy balances
3. Compile appropriate property data for chemical compounds and mixtures
4. Choose and solve appropriate equations of state
5. Use equilibrium relationships to solve chemical engineering problems
6. Acquire and apply new knowledge as needed, using appropriate learning strategies (maps to ABET Student Outcome seven) by analyzing a current environmental issue in chemical engineering

CHME 305. Transport Operations I: Fluid Flow
3 Credits (3)
Theory of momentum transport. Unified treatment via equations of change. Shell balance solution to 1-D problems in viscous flow. Analysis of chemical engineering unit operations involving fluid flow. General design and operation of fluid flow equipment and piping networks. May be repeated up to 3 credits.
Prerequisite: CHME 201.
Prerequisite/Corequisite: MATH 1521G.
Learning Outcomes
1. Mathematical Solutions: solve applied math problems involving linear ordinary differential equations with boundary conditions; solve partial differential equations that can be analytically solved with boundary conditions; identify how coordinate systems are used with ODEs and PDEs; simplify second order PDEs with assumptions; identify when an analytical solution to a PDE is possible and when numerical methods are required.
2. Basic Fluid Concepts and Calculations: identify the properties of fluids, calculate problems that involve pressure measurements, fluid statics, and fluid kinematics; describe physical phenomena of fluid flow; define and explain viscosity, density, specific gravity, surface forces, velocity fields, Newtonian vs. Non-Newtonian, laminar flow, turbulent flow, Reynold's number, and other fluid motion topics.
3. Bernoulli and Energy Equations: apply the Bernoulli equation to sets of fluid problems; solve energy balances in the context of fluids and fluid motion, distinguish between approximations of and appropriate models for Bernoulli's Equation (i.e friction losses, x, pumps, compressors, turbines, surface forces, gas-liquid flow, non-Newtonian fluids, and the Moody diagram).
4. Momentum Analysis: apply momentum balances using the governing equations of momentum to solve one dimensional velocity profile problems of external or internal viscous fluid flow; interpret the different approximations of the momentum balance; classify differential vs. integral forms of momentum analysis; and calculate problems using the Navier Stoke's Equations.
5. Special topics: identify different turbo- and fluid-machinery; explain why computational fluid dynamics is important; solve problems using external flow with applications: boundary layers, lift, drag; and calculate problems with dimensional analysis methods.

CHME 306. Transport Operations II: Heat and Mass Transfer
4 Credits (4)
Theory of heat and mass transport. Unified treatment via equations of change. Analogies between heat and mass transfer. Shell balance solution to 1-D problems in heat and mass transfer. Analysis of chemical engineering unit operations involving heat transfer. Design principles for mass transfer equipment. May be repeated up to 4 credits.
Prerequisite: CHME 305.
Prerequisite/Corequisite: MATH 392.
Learning Outcomes
1. Adopt a systematic problem solving approach, consistently and effectively.
2. Diagram heat flows for conductive, convective, and radiative processes.
3. Find and use material property values.
4. Convert and use appropriate units of energy, power, flux, etc.
5. Write conservation equations for planar, cylindrical, and spherical systems.

6. Apply assumptions such as steady state, number of dimensions, order of magnitude, and/or constant properties to simplify conservation equations.
7. Solve the energy conservation equation for the temperature distribution using appropriate boundary and/or temporal conditions.
8. Calculate heat fluxes into and out of a control volume.
9. Draw resistance circuits and calculate the overall heat transfer coefficient, U, for compound systems. 1
10. Calculate the temperature distribution, heat flux, efficiency, and effectiveness of extended surfaces such as fins. 1
11. Use lumped capacitance and exact solution models to solve transient heat transfer problems. 1
12. Calculate transport dimensionless numbers and explain what they represent. 1
13. Use fluid velocity profiles to calculate boundary layer shapes and thicknesses. 1
14. Calculate convection heat transfer coefficient, h, for external and internal flows using formulas and graphs of experimental results. 1
15. Explain the causes and relative magnitudes of free convection. 1
16. Calculate free convection coefficients using equations and experimental results. 1
17. Label key regimes and heat transfer features of boiling and condensation curves. 1
18. Compare and contrast parallel, cross, and countercurrent flow in heat exchangers. 1
19. Determine the needed surface areas and/or fluid flow rates for heat exchangers given unit operation or process energy needs. 2
20. Calculate and explain heat exchanger efficiency. 2
21. Predict likelihood and account for consequences of fouling. 2
22. Define radiation terminology such as blackbody, grey surface, emissivity, etc. 2
23. Relate surface temperature to radiation wavelength and energy. 2
24. Calculate the view factor between two surfaces and use it to calculate heat transfer. 2
25. Write and solve the mass and molar forms of the one-D mass conservation equations. 2
26. Calculate absolute and relative species velocities and fluxes. 2
27. Use heat transfer relationships and analogous equations to solve diffusion and advection mass transfer problems. 2
28. Predict which kind(s) of heat transfer will be relevant for a given situation. 2
29. Describe implications of problem solutions and perform additional “what if” calculations to understand patterns in the bigger picture.

CHME 307. Transport Operations III: Staged Operations
3 Credits (3)
Theory of mass transport. Mass transfer coefficients. Analysis of chemical engineering unit operations involving mass transfer and separations. Equilibrium stage concept. General design and operation of mass-transfer equipment and separation sequences. Restricted to Chemical Engineering Majors. May be repeated up to 3 credits.
Prerequisite: CHME 303, CHME 306.
Prerequisite/Corequisite: CHEM 313.
Learning Outcomes
1. Determine which kind of separation (e.g., distillation, adsorption, membrane, etc.) is best suited to separate a particular mixture.
2. Design various kinds of separation units to achieve a target flow rate and purity.
3. Evaluate the cost effectiveness and energy requirements of a separation.
4. Perform McCabe-Theile analysis.
5. Include efficiencies and mass transfer effects in the design of separation units.

CHME 323 L. Transport Operations and Instrumentation Laboratory
2 Credits (6P)
Laboratory experiments demonstrate the principles of process measurement and instrumentation through the determination of thermodynamic properties, transport phenomena properties, heat transfer, and material physical properties. Treatment of data includes regression techniques, analysis of error, and statistical analysis. Restricted to: Chemical Engineering majors. May be repeated up to 2 credits.
Prerequisite: I E 311.
Prerequisite/Corequisite: CHME 306.
Learning Outcomes
1. Introduce students to practical skills needed to be able to apply the scientific and engineering concepts acquired in earlier coursework and to achieve the following.
2. Organize and carry out experimental design and actual hands-on experiments.
3. Understand safety regulations and safe operation procedures in the Chemical Engineering laboratory.
4. Be able to analyze and interpret experimental data with theories learned in previous courses.
5. Write organized and cohesive technical and reports.
6. Organize and prepare standard operating procedures.
7. Work effectively in a team environment.
8. Prepare and present technical works and answer questions.

CHME 341. Chemical Kinetics and Reactor Engineering
3 Credits (3)
Analysis and interpretation of kinetic data and catalytic phenomena. Applied reaction kinetics; ideal reactor modeling; non-ideal flow models. Mass transfer accompanied by chemical reaction. Application of basic engineering principles to design, operation, and analysis of industrial reactors. Restricted to:CHME,CMEG,CH E majors. May be repeated up to 3 credits.
Prerequisite: CHME 303, CHME 306.
Learning Outcomes
1. Perform mole balances in systems involving reactions.
2. Calculate conversion in batch and flow systems.
3. Size single and staged continuous-stirred tank, and plug flow reactors.
4. Develop rate laws from mechanisms and experimental data.
5. Calculate pressure drops and the effect on kinetics in packed-bed PFRs.
6. Apply the differential and integral methods of kinetic data analysis.
7. Maximize product selectivity for systems involving multiple reactions.
8. Understand effects of non-isothermal operation and unsteady-state behavior.
9. Apply rate limiting step and quantify performance in catalytic systems. 1
10. Quantify mass transfer limitations on heterogeneous systems. 1

11. Understand the idea of a residence time distribution,and the effect on reactor ideality.

CHME 352 L. Simulation of Unit Operations
2 Credits (2P)
Definition, specification, and convergence of basic unit operations in a process simulator. Course will cover how to access variables, define and converge design specifications and converge tear/recycle streams. Restricted to:CHME majors. May be repeated up to 2 credits.
Prerequisite/Corequisite: CHME 307, CHME 341.
Learning Outcomes
1. Apply Aspen Plus programming solutions to specify and converge unit operations involving: non-rigorous balance units (RSTOIC, SEP, MIX, FSPLIT, SSPLIT DUPL); pressure changers (PUMP , COMPR, VALVE); pipe networks (PIPE, PIPELINE); heat exchangers (HEATER, HEATX); reactors and kinetic models (RPLUG, RCSTR, BATCH, REQUIL, RGIBBS);flash drums and decanters (FLASHII, DECANTER); distillation columns (DSTWU, intro to RADFRAC)

CHME 361. Engineering Materials
3 Credits (3)
Bonding and crystal structure of simple materials. Electrical and mechanical properties of materials. Phase diagrams and heat treatment. Corrosion and environmental effects. Application of concepts to metal alloys, ceramics, polymers, and composites. Selection of materials for engineering design. May be repeated up to 3 credits.
Prerequisite: CHEM 1215G or CHEM 1216.
Learning Outcomes
1. Explain the effects of composition, bonding, structure, and defects on material properties.
2. Compute the response of materials to external influences.
3. Predict rates of materials failures.
4. Select materials for applications.

CHME 370V. Discovery and Use of Radioactive Materials
3 Credits (3)
History, properties and uses of common radionuclides, including applications in fire safety, energy production, medicine, science, industry, and warfare. Impacts of radioactive materials extraction, processing, research, testing, and disposal in the Southwest. Perspectives about radioactive materials within different cultures. Management of radioactive materials by different countries.
Learning Outcomes
1. Give examples of common radionuclides and their uses.
2. Compare radioactive decay processes.
3. Describe the social, economic, and environmental impacts of radioactive materials in state, national, and global history.
4. Complete a written or creative art project that represents the attributes of a common radionuclide.
5. Present the contexts that influence the treatment and perspectives of radioactive materials within different cultures.

CHME 391. Industrial Employment
1-3 Credits (1-3)
Employment in chemical, petroleum, food, biotechnology, materials, environmental, pharmaceutical, or other industry relevant to the discipline, with opportunity for professional experience and training in chemical engineering. Requires written report covering work period approved by employer. Consent of Instructor required. Students must complete the NMSU Cooperative Education and Internship Learning Agreement. May be repeated up to 6 credits.
Learning Outcomes
1. Gain educational and work experiences that are directly related to the BSCHE curriculum and the student's career goals.
2. Develop an understanding of the demands, responsibilities, and opportunities of professional employment.
3. Be provided an opportunity to apply principles and techniques learned in the CHME curriculum to real life problem-solving situations.
4. Gain a better understanding of decision-making and implementation processes.
5. Criterion three Student Outcomes specifically addressed by this course are found in a mapping of outcomes against all CHME courses in the curriculum.

CHME 392. Numerical Methods in Engineering
3 Credits (3)
Study and application of numerical methods in solving problems commonly encountered in engineering. MATLAB will be used as the working environment for implementing and performing the numerical methods in computers.
Prerequisite/Corequisite: MATH 1521G.
Learning Outcomes
1. Use MATLAB as a tool to solve chemical engineering problems;
2. Import and graph data using MATLAB;
3. Write and use script M-files and function M-files;
4. Understand the differences between script M-files and function M-files and why they are used in different situations;
5. Be able to translate algebraic equations into matrices, and use MATLAB to solve systems of linear algebraic equations;
6. Fit equations to data, obtain parameters, and determine the goodness of fit;
7. Linearize non-linear equations and obtain parameters for the nonlinear equations;
8. Use MATLAB to symbolically and numerically integrate one-dimensional integrals;
9. Solve systems of ordinary differential equations analytically (by hand); 1
10. Solve systems of ordinary differential equations numerically and analytically using MATLAB. 1
11. Criterion three Student Outcomes specifically addressed by this course are found in a mapping of outcomes against all CHME courses in the curriculum.

CHME 395V. Brewing Science and Society
3 Credits (3)
An overview of the science of brewing and the interrelationships between society, technology, business, and the evolution of the current beer market. Topics covered are history of brewing and the interrelationships between societal attitudes, technology, and cultural preferences; beer styles and evaluation techniques; production and characteristics of ingredients used in brewing; brewing unit operations; biochemistry of malting, mashing, and fermentation; engineering in the brewery; homebrewing; and societal and health issues related to beer and alcohol. Students must be at least 21 years of age by the first day of instruction of the semester to enroll in this course. May be repeated up to 3 credits.
Learning Outcomes
1. Provide the undergraduate student with a broad perspective of beer and the brewing industry as well as technical knowledge about the brewing process.

CHME 412. Process Dynamics and Control
3 Credits (3)
Process modeling, dynamics, and feedback control. Linear control theory and simulation languages. Application of Laplace transforms and frequency response to the analysis of open-loop and closed-loop process dynamics. Dynamic response characteristics of processes. Stability analysis and gain/phase margins. Design and tuning of systems for control of level, flow, and temperature. May be repeated up to 3 credits.
Prerequisite: CHME 341.
Learning Outcomes
1. Mathematical Solutions: solve applied math problems involving linear ordinary differential equations, integration by parts, perform partial fraction expansion; use the Laplace Transform to solve differential equations; Laplace Transform look-up tables, solve inverse Laplace Transform problems.
2. Model-based Control: use MATLAB, Simulink, and/or visual basic simulator to computationally model process control, to make simple mathematic calculations, to solve differential equations, to take the Laplace Transform of a function, to plot curves representing response of a control loop, and to implement other simulation-based actions covered in class.
3. Basic Process Control Concepts and Calculations: draw and use block diagrams of open and closed-loop transfer functions for control problems; identify control system instrumentation (sensors, transmitters, transducer, final control elements); use process control techniques to address safety concerns; use process control vocabulary appropriately; choose a control strategy for a process; formulate control objectives; identify, formulate and solve linear chemical process dynamics problems; formulate and solve an approximate linear model to a nonlinear process; analyze the stability of a dynamic system.
4. PID Control Concepts: tune a P, PI, or PID controller using control theory; choose the appropriate control action (P, PI, PID) for a particular process,
5. Other topics: develop process models of non-steady-state process dynamics; Identify appropriate loop pairings for multivariable control; identify and implement feedforward and feedback control strategies; implement single-variable controllers (temperature, pressure, concentration, flow, level); and identify advanced control strategies and apply them in appropriate situations (cascade, ratio, pH).

CHME 423 L. Unit Operations Laboratory
2 Credits (6P)
Experiments with chemical engineering unit operations including the use of computer data acquisition. Covers control systems with closed-loop process control, instrumentation and development of empirical models from process data. Includes written and oral reports. May be repeated up to 2 credits.
Prerequisite: CHME 307, CHME 341.
Prerequisite/Corequisite: CHME 412.
Learning Outcomes
1. Understand and apply engineering experimentation techniques and safety procedures common to the chemical industry.
2. Apply principles developed in chemical engineering courses to the analysis of chemical engineering processes and unit operations.
3. Know the materials characterization methods.
4. Improve skills necessary for group work—interpersonal skills, coordination of the efforts of several persons, leader and subordinate roles, etc. Introduce students to practical skills needed to be able to apply the scientific and engineering concepts acquired in earlier coursework.

CHME 448. Industrial Safety
3 Credits (3)
An introduction to the fundamentals of chemical process safety, including toxicology, industrial hygiene, source models, fires and explosions, relief systems, hazard identification, risk assessment, environmental fate and transport, hazardous waste generation, pollution prevention, and regulatory requirements. May be repeated up to 3 credits.
Corequisite: CHME 323 L.
Learning Outcomes
1. Demonstrate a knowledge and understanding of the elements of process safety management.
2. Be able to pro-actively identify and analyze safety hazards.
3. Demonstrate knowledge and understanding of risk management tools, programs and processes associated with process safety.
4. Understand the OSHA PSM requirements.
5. Understand and appreciate the need for professional integrity and ethical decision making in the professional practice of engineering.
6. Demonstrate an understanding of issues encountered including business, environmental, health, safety and public interest issues.

CHME 451. Intellectual Property for Engineers and Scientists
3 Credits (3)
An overview of intellectual property with an emphasis on patents. Terminology, patentability requirements, invention disclosures, inventorship, scope of claims, patent application content and the patent prosecution process, and post-allowance matters including infringement and enforcement. May be repeated up to 3 credits.
Learning Outcomes
1. Assess what kind of protection – patent, trade secret, copyright, trademark – is appropriate for particular intellectual property.
2. Describe relevant subject matter and standards for protection under patent, trade secret, copyright, and trademark.
3. Differentiate inventorship, authorship and ownership in an intellectual property context.
4. Devise search strategies to assess ‘prior art’ and public information that may affect availability of intellectual property protection.
5. Generate sample content for a patent application (including claims) and a trademark application.
6. Analyze office actions and propose solutions for issues raised during patent prosecution and trademark prosecution.
7. Compare and contrast the procedures for obtaining a patent, securing a trademark, registering a copyright and establishing trade secret protection.
8. Describe basic considerations relating to enforcement and infringement of intellectual property.

CHME 452. Chemical Process Design & Economic Evaluation
3 Credits (3)
Concepts in chemical engineering process design, including: capital and manufacture cost estimation; discounted cash flows; interest; taxes; depreciation; profitability analysis; project specifications. May be repeated up to 3 credits.
Prerequisite: CHME 307, CHME 341.
Learning Outcomes
1. Write and explain the meanings of the basic equations related to engineering economic analysis.

2. Formulate mathematical models and solve problems involving process design and economic analysis.
3. Discuss the environmental, social, and economic implications of process design.
4. Criterion three Student Outcomes specifically addressed by this course are found in a mapping of outcomes against all CHME courses in the curriculum.

CHME 455. Chemical Plant Design
3 Credits (3)
Design and analysis of integrated process plants. Consideration given to optimizing performance, operability, reliability, safety, control, energy integration, and cost effectiveness. Requires written report covering solution of a capstone design problem. May be repeated up to 3 credits. Restricted to: CHME majors.
Prerequisite: CHME 452.
Corequisite: CHME 455L.
Learning Outcomes
1. Understand government regulation of chemical processes.
2. Be knowledgeable of process safety analysis procedures.
3. Understand "normal" process conditions vs. those of concern.
4. Be able to perform a process optimization (topological vs. parametric).
5. Be able to perform a heat integration analysis through pinch technology.
6. Use heuristics to confirm the suitability of a process design.
7. Understand how to perform a base case analysis.
8. Be able to complete an analysis of a chemical plant design that includes: base case development and justification; process simulation; topological and parametric optimizations; societal impact assessment; and economic evaluation; including making recommendations based on their findings.

CHME 455 L. Chemical Plant Simulation
1 Credit (1P)
Construction, convergence, and optimization of chemical processes in a process simulator. Dynamic process simulation and control. Taken concurrently with CHME 455. May be repeated up to 1 credit.
Prerequisite: CHME 412, CHME 352 L.
Learning Outcomes
1. Understand how to input from the Aspen Plus Graphical User Interface (GUI).
2. How to specify unit operations in Aspen Plus.
3. Be able to perform a sensitivity analysis and an optimization.
4. Understand how to apply a design specification in Aspen Plus.
5. Understand how to use Calculator Blocks such as Fortran or Excel.
6. Be able to specify a catalytic reactor with LH kinetics.
7. Be able to optimize a RADFRAC distillation column on an economic basis.
8. Be able to converge complex multicomponent RADFRAC distillations.
9. Be able to use the economics analyzer package in conjunction with a simulation.

CHME 461. Calculation of Material and Molecular Properties
3 Credits (3)
The aim is to describe and apply techniques for computing common properties of materials and molecules: optimized geometries, transition states, vibrational spectra, energies (electronic, internal energy, enthalpy, and Gibbs free energy), heat capacities, net atomic charges, atomic spin moments, and effective bond orders. These techniques allow one to estimate the thermodynamic properties of a chemical, as well as to compute the mechanisms and energy barriers for chemical reactions and catalytic processes, and to quantify the electronic, magnetic, and chemical ordering in materials. The theory behind these techniques will be described and students will perform hands-on computer exercises using common computational chemistry programs. Taught with CHME 561. May be repeated up to 3 credits.
Prerequisite: CHEM 1216 or CHEM 1226, MATH 1521G or MATH 1521H, (PHYS 2140 or PHYS 1320G).
Learning Outcomes
1. Basic concepts of computational chemistry.
2. Calculating the energies and geometries of reactants and products for chemical reactions.
3. Finding the transition state of a chemical reaction: determining the reaction pathway, transition state geometry, and the energy barrier. Meaning of the energetic span for a catalytic cycle.
4. Quantifying whether the transition state is closer to the reactant (early transition state) or closer to the product (late transition state). Postulates related to transition state lateness.
5. Computing vibrational spectra.
6. Using the harmonic approximation to estimate thermodynamics properties: internal energy, enthalpy, Gibbs free energy, and heat capacities.
7. Computing net atomic charges, atomic spin moments, and effective bond orders to determine the electronic, magnetic, and chemical ordering of materials.

CHME 464. Polymer Science & Engineering
3 Credits (3)
This course covers concepts in science and engineering of macromolecules, such as synthesis and chemistry, characterization of molecular weight, morphology, rheology, and mechanical behavior, structure and property relationships, and polymer processing. Taught with CHME 564. May be repeated up to 3 credits.
Prerequisite: CHEM 313 or CHEM 2115.
Learning Outcomes
1. Describe the fundamental concepts in polymer science and engineering;
2. Analyze the microstructure and molecular weight of polymers;
3. Discuss the chemistry, importance and applications of natural polymers;
4. Interpret different synthesis methods of polymers;
5. Analyze the kinetics of polymerization;
6. Discuss the polymer rheology and viscoelastic behavior of polymers;
7. Explain the characterization and processing of polymers; and
8. Argue the selection of polymer and/or design a specific polymer for specific applications (through final project).
9. Criterion three Student Outcomes specifically addressed by this course are found in a mapping of outcomes against all CHME courses in the curriculum.

CHME 467. Nanoscience and Nanotechnology
3 Credits (3)
This is a lecture/laboratory course designed to present the basic concepts, the techniques and the tools to synthesize and characterize nanometer scale materials, and the latest achievements in current and future nanotechnology applications in engineering, materials, physics, chemistry, biology, electronics and energy. It is intended for a multidisciplinary audience with a variety of backgrounds. This

course should be suitable for graduate students as well as advanced undergraduates. Topics covered will include: nanoscience and nanotechnology, nanofabrication, self-assembly, colloidal chemistry, sol-gel, carbon nanotubes, graphene, thin film, lithography, physical vapor deposition, chemical vapor deposition, quantum dots, lithium batteries, X-ray diffraction, scanning electron microscopy, transmission electron microscopy, nanoelectronics, nanophotonics and nanomagnetics, etc. Students must also have completed (EH&S Safety training to include the courses: (1) Employee & Hazard Communication Safety (HazCom); (2) Hazardous Waste Management; and (3) Laboratory Standard) trainings to enroll. Crosslisted with: PHYS 520 . May be repeated up to 3 credits.
Prerequisite: (CHEM 1216 or CHEM 1226), (PHYS 1230G or PHYS 1310G).

Learning Outcomes

1. Understand the basic and state-of-art synthesis methods and applications in nanoscience and nanotechnology (Student outcome (a) an ability to apply knowledge of mathematics, science, and engineering).
2. Do lab work to use tools and analyze data (Student outcome (b) an ability to design and conduct experiments, as well as to analyze and interpret data).
3. Form a team for lab work and lab report (Student outcome (d) an ability to function on multidisciplinary teams).
4. Present literature review and ask questions (Student outcome (g) an ability to communicate effectively).

CHME 470. Introduction to Nuclear Energy
3 Credits (3)
Atomic and nuclear structure, nuclear stability and radioactivity, nuclear reactions, detection and measurement of radiation, interaction of radiation with matter, radiation doses and hazard assessment, principles of nuclear reactors, and applications of nuclear technology. Taught with CHME 570. May be repeated up to 3 credits.
Prerequisite: CHEM 1215G or CHEM 1225G, MATH 1521G or MATH 1521H.

Learning Outcomes

1. Basic Concepts. Write and explain the meanings of the basic balances and equations of nuclear science and engineering.
2. Problem Solving. Solve problems involving radioactive decay rates, radiation interactions, rates of nuclear reactions, energies of nuclear transformations, and applications.
3. Model Building. Given a verbal or pictorial description, create useful mathematical models of nuclear engineering systems, such as radiation shields, radiation detectors, nuclear reactors, and energy converters.
4. Social and Economic Effects. Discuss the global environmental, social, and economic effects of nuclear technology.

CHME 471. Health Physics
3 Credits (3)
Introduction to radiation protection, radiation/radioactivity, radioactive decay/fission, interactions of radiation and matter, biological effects of radiation, radiation measurement and statistics, sampling for radiation protection, radiation dosimetry, environmental transport, radiation protection guidance, external and internal radiation protection, and hazards analysis. Taught with CHME 571.
Prerequisite(s): MATH 1521G or MATH 1521H, CHME 470.

Learning Outcomes

1. Develop the ability to solve problems using the equations to calculate: a. Atomic Structure and Atomic Radiation: binding and ionization energies, atomic densities, characteristic X-rays and Auger electrons. b. The Nucleus and Nuclear Radiation: nuclear binding energies, alpha particle energy and recoil nucleus energy in an interaction, calculate Q of beta particle, antineutrino, recoil nucleus, orbital electron, internal conversion electron, and internal conversion coefficient. c. Interaction of heavy charged particles, beta and gamma radiation with matter: maximum energy transfer, stopping power, mean excitation energies, range and slowing down time. collisional stopping power, radiative stopping power, radiation yield, range, slowing-down time. Photon threshold energy, energy of the scattered photon and the Compton shift in wavelength, momentum of the scattered photon, average kinetic energy of Compton Recoil electrons, linear and mass attenuation coefficients, threshold energy and atomic cross section for the photodisintegration of a radionuclide, rate of energy absorption per unit mass. d. Statistics Know the concepts of Statistics of radioactive disintegration, the Binomial Poisson Normal distributions, error and error propagation, counting rates, Criteria for Radiobioassay. Calculate Minimum Significant Measured Activity, Type-I Errors, Minimum Detectable True Activity, Type-II Errors. e. Radiation Dosimetry: Know and calculate the units of exposure, absorbed dose, dose equivalent, kerma, specific energy, lineal energy; alpha and low-energy beta emitters distributed in tissue, charged-particle beams, point source of gamma rays, neutrons; measurement of exposure, absorbed dose, X- and Gamma-Ray, neutron dose.
2. Know the concepts of: a. Radiation Detection and measurements methods: Ionization in gases, Ionization current, W values, Ionization pulses, Gas-filled detectors, Ionization in semiconductors, Band theory of solids, semiconductors, Radiation measuring devices; Scintillators, Organic and Inorganic scintillation detectors; Photographic Film; Thermoluminescence, Optically stimulated luminescence, Radiophotoluminescence, Chemical dosimeters, Calorimetry, Cerenkov detectors, Neutron Detection: Slow, Intermediate and Fast Neutrons. b. Chemical and Biological Effects of Radiation: Radiation effects time frame, physical and prechemical chances in irradiated water, chemical yields in water; Sources of Human Data biological effects: The life span study, medical radiation, radium-dial painters, uranium miners, accidents, acute radiation syndrome; Delayed somatic effects: Cancer, life shortening cataracts; Dose–response relationships, factors affecting dose response, relative biological effectiveness, dose rate, oxygen enhancement ratio, chemical modifiers. c. Radiation-Protection Criteria and Exposure Limits: Become knowledgeable about objectives of radiation protection, elements of radiation-protection programs, The NCRP and ICRP; NCRP/ICRP Dosimetric Quantities: Equivalent dose, Effective dose, Committed equivalent dose, Committed effective dose ,Limits on intake; Risk estimates for radiation protection; Current exposure limits of the NCRP and ICRP. Occupational limits, Non-occupational limits Exposure of individuals under 18 Years of age; Occupational limits in the Dose-Equivalent System -The “2007 ICRP Recommendations”. d. Internal Dosimetry and Radiation Protection: ICRP-30 Dosimetric Model for the Respiratory System and Gastrointestinal Tract, ICRP-66 Human Respiratory Tract Model, ICRP-30 Dosimetric Model for the Organ Activities as Functions of Time, for Submersion in a Radioactive Gas Cloud , Metabolic Data for Reference Man, ICRP Publication 89, Specific Absorbed Fraction, Specific Effective Energy, and Committed Quantities; Number of Transformations in Source Organs over 50 Y. e. External Radiation Protection: Design concepts of distance, time, and shielding for radiation protection, primary and secondary protective barriers; shielding of Gamma-Ray, X-rays, beta and neutron radiation, ICRP Report.

3. Hands on experience with background radiation and contamination measurement, concepts of statistical variation of radiation measurement.
4. Term Paper group interaction, writing manuscript, and personal presentation.

CHME 474. Power Plant Design
3 Credits (3)
Principles of electric power generation. Review of DC and AC systems, energy sources, and prime movers. Analysis of hydroelectric, fossil fuel, nuclear, and alternative power systems. Environmental and economic considerations. Taught with CHME 574. May be repeated up to 3 credits.
Prerequisite: MATH 1511G or MATH 1521H, CHEM 1215G or CHEM 1216G.
Learning Outcomes
1. Write and explain the meanings of the basic concepts and equations related to electric power generation.
2. Formulate mathematical models and solve problems involving electric power generation.
3. Summarize the economic, environmental, and regulatory issues involving electric power generation.

CHME 476. Nuclear Fuel Cycles
3 Credits (3)
Physical and chemical processes in the conventional nuclear fuel cycle: uranium mining and milling, conversion, enrichment, fuel fabrication, reactor operations, interim storage, reprocessing and recycling, waste treatment and disposal. Alternative fuel cycles and future prospects. Taught with CHME 576. May be repeated up to 3 credits.
Prerequisite: CHME 470.
Learning Outcomes
1. Write and explain the basic principles and equations related to the conventional nuclear fuel cycle.
2. Solve problems involving chemical and nuclear processes in the conventional nuclear fuel cycle.
3. Given a verbal or pictorial description, create useful mathematical models of chemical engineering systems in the nuclear fuel cycle.
4. Discuss the global environmental, social, and economic implications of nuclear fuel cycles.

CHME 478. Electrochemistry: Basics & Applications
3 Credits (3)
Theory and application of electrochemical devices. Topical information related to electrochemistry are concepts, principles, and examples of energy storage, mechanisms responsible for electrochemical devices, and current progress and problems. Relevant devices covered include the lithium ion battery, supercapacitor, fuel cell, solar cell and electrolyzer.
Learning Outcomes
1. Understand the mechanisms responsible for electrochemical device.
2. Realize the current progress in electrochemistry.
3. Identify the problems and hurdles for electrochemical device practical applications.

CHME 479. Corrosion and Degradation of Materials
3 Credits (3)
Failure of engineering materials in aggressive environments. Chemical and electrochemical mechanisms of corrosion. Influence of chemical composition and microstucture on corrosion behavior. Types of corrosion and chemical attack, including uniform corrosion, galvanic corrosion, pitting and other forms of localized corrosion, stress corrosion cracking, and corrosion fatigue. Methods of corrosion mitigation including cathodic protection, coatings, passivation, and corrosion inhibitors. Corrosion in nuclear reactors and nuclear waste repositories. May be repeated up to 3 credits.
Prerequisite: CHME 361.
Learning Outcomes
1. Basic Concepts: Explain the basic principles related to the corrosion and degradation of materials.
2. Problem Solving: Solve problems involving mechanical, chemical and electrochemical processes in materials exposed to harsh environments.
3. Mitigation: Discuss methods for preventing the degradation and failure of materials.

CHME 481. Biomedical Engineering and Engineering Healthcare
3 Credits (3)
Orientation to solving human and world health issues with biological engineering systems, tools, and analysis methods. Introduces general concepts including applied biology for engineers, biophotonics, biosensing, bioinstrumentation, tissue and biomaterials engineering, biomedical engineering research practices, and physical bioanalytical methods. May be repeated up to 3 credits.
Prerequisite: CHEM 1215 or CHEM 1225.
Learning Outcomes
1. Solve problems related to the design of biomedical instruments.
2. Apply basic mathematics, biology concepts, and laws of physics and chemistry to solve biomedical engineering type problems.
3. Explain differences in biomedical research and industries.
4. Identify the current challenges in the field of biomedical engineering and predict what investigators and industries are doing to tackle such problems.
5. Critique biomedical engineering research through interpretation of peer-reviewed literature, formal presentations and formal reports.
6. Design a solution to a current biomedical engineering problem by computational modeling, experimental design, and/or researching a specific subject in biomedical engineering (i.e. reading peer-reviewed research articles/manuscripts/textbooks).
7. Engage in hands-on learning of biomedical devices such as the building of a simple flow-cytometer.

CHME 486. Biofuels
3 Credits (3)
Introduction to the fundamentals and applications of biofuels and bioenergy production; biomass resources and their composition; types of biofuels; conversion technologies (thermochemical and biochemical conversion processes); biodiesel production, algae to biofuels; economic and environmental assessments; term paper of selected topics relevant to biofuels. May be repeated up to 3 credits.
Prerequisite: CHEM 313 or consent of instructor.
Learning Outcomes
1. Understand basic concepts about biomass derived energy;
2. Identify potential biomass feedstocks including energy crops;
3. Understand the concept of 1st generation, 2nd generation and advance biofuels;
4. Understand terminologies related to biomass conversion and biofuel production;
5. Have an understanding of the existing and emerging biomass to energy technologies;
6. Understand and apply mass and energy balances in biomass conversion;

7. Apply engineering thermodynamics, organic chemistry, chemistry of plant materials;
8. Familiarize with characterization of biomass feedstocks;
9. Understand the unit processes/ unit operations involved in biofuel/ bioenergy production; 1
10. Be able to do the basic engineering calculations related to biofuel production; 1
11. Understand the concept of a biorefinery system and be able to develop major unit operations of an integrated biorefinery; 1
12. Describe techno-economic analyses of biofuel conversion technologies; 1
13. Have an understanding of environmental implications; and 1
14. Apply biomass-derived energy in different applications.

CHME 490. Senior Seminar
1 Credit (1)
Research seminar attended by graduate students is open to CHME undergraduates who are research active May be repeated up to 2 credits. Students must be in Senior Standing to enroll in this course.
Prerequisite(s)/Corequisite(s): CHME 498.
Learning Outcomes
1. Expose students to the breadth and depth of research in chemical engineering and related fields.

CHME 491. Undergraduate Special Topics
3 Credits (3)
Lecture and/or laboratory instruction on special topics in chemical engineering. May be repeated up to 6 credits.
Learning Outcomes
1. Gain exposure to, knowledge of, and practice solving problems in a variety of CHME topics that are directly related to broadening the BSCHE curriculum and the student's career goals.
2. Topics will vary by years and section depending on current topics of interest in CHME and availability of instructors.
3. be provided an opportunity to apply principles and techniques learned in the CHME curriculum to real life problem-solving situations in specialized topics.

CHME 495. Brewing Science & Engineering
3 Credits (3)
Details of beer production, fermentation science, brewery operation, and process design & economics. Engineering considerations including process safety, fermentation kinetics, unit operations, and economies of scale. Beer styles, recipe formulation, product quantification for tax purposes, and brew analytical methods will also be discussed. Students must be 21 years old to enroll. Crosslisted with: FSTE 430.
Learning Outcomes
1. To provide the undergraduate student with a broad perspective of beer and the brewing industry as well as technical knowledge about the brewing process.

CHME 495 L. Brewing Science & Technology Lab
1 Credit (3P)
Brewing and brewing operations in a one-barrel brewery. Topics addressed will include brewery safety, characteristics and handling of brewing ingredients, recipe formulation, water treatment, wort preparation, fermentation, waste disposal, and packaging.
Prerequisite/Corequisite: CHME 495.
Learning Outcomes
1. Demonstrate a working 1-barrel brewery and its unit operations, from recipe formulation to brewing and fermentation to cleaning and sanitizing.

CHME 497. Undergraduate Special Projects
1-3 Credits (1-3)
Provides an opportunity for undergraduate students to work on special projects under the direction of a faculty member. Written report covering work is required. May be repeated up to 6 credits.
Learning Outcomes
1. Prepare a written project report conforming to the format of the CHME writing standard.
2. Articulate a clear project question or problem.
3. Define, articulate, and use appropriate terminology and concepts.
4. Use library and other tools to search for existing body of information relevant to their project.
5. Identify and practice appropriate engineering ethics.
6. Know and apply problem solving skills to constructively address setbacks.
7. Work collaboratively with others, using listening and communication skills.
8. Work autonomously in an effective manner, setting and meeting deadlines.
9. Reflect on own project outcomes, identifying lessons learned, strengths, and ways to improve. 1
10. Communicate confidently and constructively with students, faculty, and project sponsor (as required). 1
11. Explain project to others in the field and to broader audiences through presentations. 1
12. Articulate the relevance of their project to their coursework and professional future, synthesizing their project, academic, and professional interests and goals.

CHME 498. Undergraduate Research
1-3 Credits (1-3P)
Provides an opportunity for undergraduate students to work in research studies under the direction of a faculty member. Consent of Instructor required. May be repeated up to 6 credits.
Learning Outcomes
1. Prepare a written research report conforming to the format of the CHME writing standard.
2. Articulate a clear research question or problem and formulate a hypothesis.
3. Identify and demonstrate appropriate research methodologies.
4. Define, articulate, and use appropriate terminology, concepts, and theory.
5. Use library and other tools to search for existing body of research relevant to their topic.
6. Know existing body of research relevant to their topic and explain how their project fits.
7. Identify and practice research ethics and responsible conduct in research.
8. Know and apply problem solving skills to constructively address research setbacks.
9. Work collaboratively with other researchers, using listening and communication skills. 1

10. Work autonomously in an effective manner, setting and meeting deadlines. 1
11. Reflect on own research, identifying lessons learned, strengths, and ways to improve. 1
12. Communicate confidently and constructively with graduate students, other researchers, and faculty. 1
13. Explain research to others in the field and to broader audiences through presentations. 1
14. Articulate the relevance of their research to their coursework and professional future, synthesizing their research, academic, and professional interests and goals. 1
15. Criterion Three Student Outcomes specifically addressed by this course are NOT found in a mapping of outcomes against all CHME courses in the curriculum as this is a technical elective, not a required core course.

CHME 501. Graduate Thermodynamics for Chemical Engineers
3 Credits (3)
Advanced applications of the first and second law to chemical process systems. The calculus of thermodynamics, equilibrium and stability criteria. Properties relationships for real fluids, both pure materials and mixtures. An introduction to molecular thermodynamics and statistical mechanics. Restricted to: CHME,CH E majors. May be repeated up to 3 credits.

Learning Outcomes
1. Solve problems using the energy balance appropriate for a system (the First Law of Thermodynamics).
2. Solve problems using the entropy balance appropriate for a system (the Second Law of Thermodynamics).
3. Evaluate, manipulate, and use thermodynamic partial derivatives.
4. Correctly use thermodynamic property charts, steam tables, and other relations to determine the thermodynamic properties of real substances and mixtures.
5. Determine whether a system is at equilibrium and whether it is stable.
6. Use the thermodynamic relationships governing phase changes.
7. Apply the basic relations of statistical thermodynamics and how to apply them.

CHME 506. Graduate Transport Phenomena(s)
3 Credits (3)
Covers the analysis of simultaneous momentum, energy, and mass transport. Development of integral and local balance equations in vector-tensor form. Application of vector-tensor analysis to transport equations. Boundary layer theory and turbulence. May be repeated up to 3 credits.

Learning Outcomes
1. Perform vector and tensor analysis.
2. Formulate momentum, heat, and mass transport equations.
3. Analyze and solve macroscopic momentum, heat, and mass balances for steady and quasi-steady-state problems.
4. Formulate the transport phenomena in boundary layer.
5. Compare the difference in between laminar and turbulent flows.
6. Differentiate polymeric and non-Newtonian fluids.
7. Demonstrate the analogies between momentum, heat and mass transfer problems.

CHME 516. Graduate Numerical Methods in Chemical Engineering
3 Credits (3)
Survey of numerical methods for solving problems commonly encountered in heat and mass transfer, fluid mechanics, and chemical reaction engineering. May be repeated up to 3 credits.

Learning Outcomes
1. Understand criteria to evaluate and compare the performance of different numeric methods.
2. Solve linear and nonlinear systems of equations for several unknown variables.
3. Numerically solve ordinary and partial differential equations to solve both initial and boundary value problems.
4. Numerically optimize functions to find zeros, minima, and maxima.
5. Use and understand the key differences between different numerical methods.
6. Solve basic problems in statistics and data regression for model parameter estimation.
7. Prepare Matlab programs using user-defined functions and scripting files.
8. Use Matlab to manipulate data plots.
9. Use Matlab to perform both symbolic and numeric integration of mathematical functions. 1
10. Apply these numerical methods to the solution of Chemical Engineering problems, including batch reaction kinetics, heat transfer, mass transfer, and vapor-liquid equilibria calculations. 1
11. Understand and use Matlab control structures, including iterative loops and “ IF … THEN” blocks.

CHME 542. Graduate Reactor Analysis and Design (s)
3 Credits (3)
Application and analysis of equations of continuity to multicomponent reaction systems. Introduction to homogeneous and heterogeneous catalysis, single-phase combustion, and shock reaction systems. May be repeated up to 3 credits.

Learning Outcomes
1. Perform mole balances in systems involving chemical reaction.
2. Calculate conversion in batch and flow systems.
3. Size single and staged continuous-stirred tank, and plug flow reactors.
4. Develop rate laws from mechanisms and experimental data.
5. Calculate pressure drops and the effect on kinetics in packed-bed PFRs.
6. Apply the differential and integral methods of kinetic data analysis.
7. Maximize product selectivity for systems involving multiple reactions.
8. Understand effects of non-isothermal operation and unsteady-state behavior.
9. Apply rate limiting step and quantify performance in catalytic systems. 1
10. Quantify mass transfer limitations on heterogeneous systems. 1
11. Understand the idea of a residence time distribution, and the effect on reactor ideality.

CHME 548. Industrial Safety
3 Credits (3)
Same as CHME 448 with graduate-level projects.
Prerequisite: CHEM 1216 or CHEM 1215G.

Learning Outcomes
1. Demonstrate a knowledge and understanding of the elements of process safety management.
2. Pro-actively identify and analyze safety hazards.

3. Demonstrate knowledge and understanding of risk management tools, programs and processes associated with process safety.
4. Understand the OSHA PSM requirements.
5. Understand and appreciate the need for professional integrity and ethical decision making in the professional practice of engineering.
6. Demonstrate an understanding of issues encountered including business, environmental, health, safety and public interest issues.
7. Analyze scenarios for a mock chemical plants and prepare risk analysis presentations both individually and as a group project.
8. Apply the above to a research environment.

CHME 564. Polymer Science & Engineering
3 Credits (3)
Synthesis, structure, property relationships of synthetic polymers. Taught with CHME 464. May be repeated up to 3 credits.
Prerequisite: CHME 201, CHEM 314.
Learning Outcomes
1. Describe the fundamental concepts in polymer science and engineering.
2. Analyze the microstructure and molecular weight of polymers.
3. Discuss the chemistry, importance and applications of natural polymers.
4. Interpret different synthesis methods of polymers.
5. Analyze the kinetics of polymerization.
6. Discuss the polymer rheology and viscoelastic behavior of polymers.
7. Explain the characterization and processing of polymers.
8. Argue the selection of polymer and/or design a specific polymer for specific applications (through final project).

CHME 565. Rheology and Viscoelasticity
3 Credits (3)
This course is an introduction to rheology and viscoelasticity. In particular, the flow behavior of Non-Newtonian Fluids and Viscoelastic Fluids will be covered. Rheometry, the technique for characterization of fluids, will be discussed. Most of the course is quantitative and uses mathematical modeling. Taught with CHME 465.
Prerequisite(s): CHME 306.

CHME 567. Nanoscience and Nanotechnology
3 Credits (3)
This is a lecture/laboratory course designed to present the basic concepts, the techniques and the tools to synthesize and characterize nanometer scale materials, and the latest achievements in current and future nanotechnology applications in engineering, materials, physics, chemistry, biology, electronics and energy. It is intended for a multidisciplinary audience with a variety of backgrounds. This course should be suitable for graduate students as well as advanced undergraduates. Topics covered will include: nanoscience and nanotechnology, nanofabrication, self-assembly, colloidal chemistry, sol-gel, carbon nanotubes, graphene, thin film, lithography, physical vapor deposition, chemical vapor deposition, quantum dots, lithium batteries, X-ray diffraction, scanning electron microscopy, transmission electron microscopy, nanoelectronics, nanophotonics and nanomagnetics, etc. Taught with CHME 467. May be repeated up to 3 credits.
Prerequisite: (CHEM 1225G or CHEM 1226) and (PHYS 1230G or PHYS 1310G).
Learning Outcomes
1. Understand the basic and state-of-art synthesis methods and applications in nanoscience and nanotechnology (student outcome (a) an ability to apply knowledge of mathematics, science, and engineering).
2. Do lab work to use tools and analyze data (Student outcome (b) an ability to design and conduct experiments, as well as to analyze and interpret data).
3. Form a team for lab work and lab report (Student outcome (d) an ability to function on multidisciplinary teams).
4. Present literature review and ask questions (Student outcome (g) an ability to communicate effectively).

CHME 570. Introduction to Nuclear Energy
3 Credits (3)
Atomic and nuclear structure, nuclear stability and radioactivity, nuclear reactions, detection and measurement of radiation, interaction of radiation with matter, radiation doses and hazard assessment, principles of nuclear reactors, and applications of nuclear technology. Taught with CHME 470. May be repeated up to 3 credits.
Learning Outcomes
1. Basic Concepts. Write and explain the meanings of the basic balances and equations of nuclear science and engineering.
2. Problem Solving. Solve problems involving radioactive decay rates, radiation interactions, rates of nuclear reactions, energies of nuclear transformations, and applications.
3. Model Building. Given a verbal or pictorial description, create useful mathematical models of nuclear engineering systems, such as radiation shields, radiation detectors, nuclear reactors, and energy converters.
4. Social and Economic Effects. Discuss the global environmental, social, and economic effects of nuclear technology.

CHME 571. Health Physics
3 Credits (3)
Introduction to radiation protection, radiation/radioactivity, radioactive decay/fission, interactions of radiation and matter, biological effects of radiation, radiation measurement and statistics, sampling for radiation protection, radiation dosimetry, environmental transport, radiation protection guidance, external and internal radiation protection, and hazards analysis. Taught with CHME 471.
Prerequisite: MATH 1521G or MATH 1521H, CHME 470 or CHME 570.
Learning Outcomes
1. Develop the ability to solve problems using the equations to calculate: a. Atomic Structure and Atomic Radiation: binding and ionization energies, atomic densities, characteristic X-rays and Auger electrons. b. The Nucleus and Nuclear Radiation: nuclear binding energies, alpha particle energy and recoil nucleus energy in an interaction, calculate Q of beta particle, antineutrino, recoil nucleus, orbital electron, internal conversion electron, and internal conversion coefficient. c. Interaction of heavy charged particles, beta and gamma radiation with matter: maximum energy transfer, stopping power, mean excitation energies, range and slowing down time. collisional stopping power, radiative stopping power, radiation yield, range, slowing-down time. Photon threshold energy, energy of the scattered photon and the Compton shift in wavelength, momentum of the scattered photon, average kinetic energy of Compton Recoil electrons, linear and mass attenuation coefficients, threshold energy and atomic cross section for the photodisintegration of a radionuclide, rate of energy absorption per unit mass. d. Statistics Know the concepts of Statistics of radioactive disintegration, the Binomial Poisson Normal distributions, error and error propagation, counting rates, Criteria for Radiobioassay. Calculate Minimum Significant Measured Activity, Type-I Errors, Minimum Detectable True

Activity, Type-II Errors. e. Radiation Dosimetry: Know and calculate the units of exposure, absorbed dose, dose equivalent, kerma, specific energy, lineal energy; alpha and low-energy beta emitters distributed in tissue, charged-particle beams, point source of gamma rays, neutrons; measurement of exposure, absorbed dose, X- and Gamma-Ray, neutron dose.

2. Know the concepts of: a. Radiation Detection and measurements methods: Ionization in gases, Ionization current, W values, Ionization pulses, Gas-filled detectors, Ionization in semiconductors, Band theory of solids, semiconductors, Radiation measuring devices; Scintillators, Organic and Inorganic scintillation detectors; Photographic Film; Thermoluminescence, Optically stimulated luminescence, Radiophotoluminescence, Chemical dosimeters, Calorimetry, Cerenkov detectors, Neutron Detection: Slow, Intermediate and Fast Neutrons. b. Chemical and Biological Effects of Radiation: Radiation effects time frame, physical and prechemical chances in irradiated water, chemical yields in water; Sources of Human Data biological effects: The life span study, medical radiation, radium-dial painters, uranium miners, accidents, acute radiation syndrome; Delayed somatic effects: Cancer, life shortening cataracts; Dose-response relationships, factors affecting dose response, relative biological effectiveness, dose rate, oxygen enhancement ratio, chemical modifiers. c. Radiation-Protection Criteria and Exposure Limits: Become knowledgeable about objectives of radiation protection, elements of radiation-protection programs, The NCRP and ICRP; NCRP/ICRP Dosimetric Quantities: Equivalent dose, Effective dose, Committed equivalent dose, Committed effective dose ,Limits on intake; Risk estimates for radiation protection; Current exposure limits of the NCRP and ICRP. Occupational limits, Non-occupational limits Exposure of individuals under 18 Years of age; Occupational limits in the Dose-Equivalent System -The 2007 ICRP Recommendations. d. Internal Dosimetry and Radiation Protection: ICRP-30 Dosimetric Model for the Respiratory System and Gastrointestinal Tract, ICRP-66 Human Respiratory Tract Model, ICRP-30 Dosimetric Model for the Organ Activities as Functions of Time, for Submersion in a Radioactive Gas Cloud , Metabolic Data for Reference Man, ICRP Publication 89, Specific Absorbed Fraction, Specific Effective Energy, and Committed Quantities; Number of Transformations in Source Organs over 50 Y. e. External Radiation Protection: Design concepts of distance, time, and shielding for radiation protection, primary and secondary protective barriers; shielding of Gamma-Ray, X-rays, beta and neutron radiation, ICRP Report.
3. Hands on experience with background radiation and contamination measurement, concepts of statistical variation of radiation measurement.
4. Term Paper group interaction, writing manuscript, and personal presentation.

CHME 574. Power Plant Design
3 Credits (3)
Principles of electric power generation. Review of DC and AC systems, energy sources, and prime movers. Analysis of hydroelectric, fossil fuel, nuclear, and alternative power systems. Environmental and economic considerations. Taught with CHME 474. May be repeated up to 3 credits.
Learning Outcomes
1. Write and explain the meanings of the basic concepts and equations related to electric power generation.
2. Formulate mathematical models and solve problems involving electric power generation.
3. Summarize the economic, environmental, and regulatory issues involving electric power generation.

CHME 576. Nuclear Fuel Cycles
3 Credits (3)
Physical and chemical processes in the conventional nuclear fuel cycle: uranium mining and milling, conversion, enrichment, fuel fabrication, reactor operations, interim storage, reprocessing and recycling, waste treatment and disposal. Alternative fuel cycles and future prospects. Taught with CHME 476. May be repeated up to 3 credits.
Learning Outcomes
1. Write and explain the basic principles and equations related to the conventional nuclear fuel cycle.
2. Solve problems involving chemical and nuclear processes in the conventional nuclear fuel cycle.
3. Given a verbal or pictorial description, create useful mathematical models of chemical engineering systems in the nuclear fuel cycle.
4. Discuss the global environmental, social, and economic implications of nuclear fuel cycles.

CHME 578. Electrochemistry: Basics & Applications
3 Credits (3)
Theory and application of electrochemical devices. Topical information related to electrochemistry are concepts, principles, and examples of energy storage, mechanisms responsible for electrochemical devices, and current progress and problems. Relevant devices covered include the lithium ion battery, supercapacitor, fuel cell, solar cell and electrolyzer.
Prerequisite: CHEM 1215G or CHEM 1216.
Learning Outcomes
1. Understand the mechanisms responsible for electrochemical devices, realize the current progress and identify the problems that challenge the practical applications.

CHME 590. Graduate Seminar
1 Credit (1)
Presentations on topics of professional interest in chemical engineering. Includes seminars by faculty, graduate students, and invited speakers from academia, government, and industry. May be repeated up to 6 credits.
Learning Outcomes
1. Expose students to the breadth and depth of research in chemical engineering and related fields.

CHME 591. Graduate Special Topics
1-3 Credits (1-3)
Lecture and/or laboratory instruction on special topics in chemical engineering. May be repeated up to 12 credits.
Learning Outcomes
1. Gain exposure to, knowledge of, and practice solving problems in a variety of CHME topics that are directly related to broadening the MSCHE, MECPI, and PHDCHE curriculum and the student's career goals.
2. Topics will vary by years and section depending on current topics of interest in CHME and availability of instructors.
3. Be provided an opportunity to apply principles and techniques learned in the CHME curriculum to real life problem-solving situations in specialized topics.

CHME 593. Graduate Special Projects
1-3 Credits (1-3)

Provides an opportunity for graduate students to work on special projects under the direction of a faculty member. Written report covering work is required. May be repeated up to 6 credits.

Learning Outcomes

1. Prepare a written project report conforming to the format of the CHME writing standard.
2. Articulate a clear project question or problem.
3. Define, articulate, and use appropriate terminology and concepts.
4. Use library and other tools to search for existing body of information relevant to their project.
5. Identify and practice appropriate engineering ethics.
6. Know and apply problem solving skills to constructively address setbacks.
7. Work collaboratively with others, using listening and communication skills.
8. Work autonomously in an effective manner, setting and meeting deadlines.
9. Reflect on own project outcomes, identifying lessons learned, strengths, and ways to improve. 1
10. Communicate confidently and constructively with students, faculty, and project sponsor (as required). 1
11. Explain project to others in the field and to broader audiences through presentations. 1
12. Articulate the relevance of their project to their coursework and professional future, synthesizing their project, academic, and professional interests and goals.

CHME 594. Professional Communication in Chemical Engineering
2 Credits (2)

Connections between interpersonal relationships and the effective communication of information. Strategies for formal and informal written and verbal communication in the context of presentations, interviews, reports and publications. Factors affecting non-verbal communication. Special focus will be given to understanding and adapting to the audience's perspective. 2 credits. Open to chemical engineering graduate students or by permission of instructor. This class will prepare you to communicate technical information effectively within a variety of contexts and to a variety of audiences. Class assignments will be partially based on current student needs such as preparing presentations for professional conferences, giving research progress reports, and writing research manuscripts. Restricted to: CHME majors. May be repeated up to 2 credits.

Learning Outcomes

1. Describe why and how interpersonal relationships affect communication of information, even within technical contexts.
2. Describe and implement methods for improving interpersonal relationships; introduce themselves to others, implement strategies for dealing with conflicts.
3. Assess the rhetorical situation for a given communication.
4. Display evidence and reasoning as well as convey credibility.
5. Understand different stakeholder audiences, and how to communicate with them differently.
6. Analyze the consequences of actions and ethical principles.
7. Design documents for users, including dividing content into manageable units.
8. Write a manuscript for the research community, including appropriate citations; manage time to allow for revisions and peer evaluation, provide useful feedback to peers during the revision process, find, understand and follow directions for manuscript and proposal preparation, locate relevant peer-reviewed journal articles using library and web resources.
9. Choose precise, accurate and concise language, and eliminate jargon, prepare effective graphs, illustrations, tables and equations. 1
10. Prepare, rehearse and deliver a research presentation.

CHME 595. Chemical Process Design and Business Analysis
3 Credits (3)

Graduate chemical process design principles, emphasizing literature review, patent search, heuristics application, process simulation assistance to process creation, synthesis of reactor and separator trains, second-law analysis, heat and power integration, process equipment mechanical design specifications, process design optimization, cost accounting and capital estimation, annual costs, earnings, and profitability analysis.

Prerequisite: CHME 452, CHME 455 L or equivalent.

Prerequisite/Corequisite: CHME 506, CHME 516, CHME 542.

Learning Outcomes

1. Make a definitive estimate or project control.
2. Perform research on the process.
3. Identify the equipment, instrumentation needed.
4. Summarize the safety aspects.
5. Identify the environmental impact.
6. List local/state/federal regulations.
7. Provide a cost estimate from vendor costs.
8. Provide sketches and drawings for the plant or system (e.g. PIDs, plot plans, evaluation diagrams, energy balances, and final PFDs with stream tables/mass balances).
9. Provide final cohesive report.

CHME 596. Chemical Process Industries Research
1 Credit (1)

Independent graduate-level chemical process design project development, literature search, and proposal/defense.

Prerequisite: CHME 595.

Learning Outcomes

1. Information about the entire process, the equipment, the instrumentation (background).
2. Information about safety aspects (even if this is existing and not new).
3. Environmental control, local/state/federal regulations, etc.
4. Prepare and defend a comprehensive report.

CHME 597. Advanced Chemical Process Industry Analysis
2 Credits (2)

In-depth analysis and defense of a timely commercially-relevant chemical process design.

Prerequisite: CHME 596.

Learning Outcomes

1. Prepare a final report that is comprehensive.
2. Data collected, an analysis related to yield, or anything else that would be appropriate as a final discussion/conclusions/recommendations about the process.
3. Add figures/graphs/tables as well as sketches and drawings for the plant PIDs, plot plans, elevation diagrams, energy balances, final PFDs with stream tables/mass balances.

CHME 599. Master's Thesis
1-15 Credits (1-15)

Thesis.

CHME 690. Graduate Seminar
1 Credit (1)
Presentations on topics of professional interest in chemical engineering. Includes seminars by faculty, graduate students, and invited speakers from academia, government, and industry. Required each semester for every Ph.D. student. All candidates for graduate degrees required to give seminar. May be repeated up to 8 credits.

Learning Outcomes

1. Expose students to the breadth and depth of research in chemical engineering and related fields.

CHME 698. Ph.D. Research
1-9 Credits (1-9P)
Advanced topics for current research. Course subtitled in the Schedule of Classes. May be repeated up to 99 credits.

Learning Outcomes

1. To make progress toward a PhD degree.

CHME 700. Doctoral Dissertation
1-9 Credits (1-9)
Individual research in selected topics of current interest in chemical engineering. May be repeated up to 88 credits.

Learning Outcomes

1. Demonstrate skills in the (a) design of experiments or simulations, (b) collection of experimental/simulated data, (c) development of appropriate models, and (d) make appropriate use of those models;
2. Complete an independent research project, resulting in at least a thesis/dissertation and peer-reviewed journal article(s);
3. Defend original research in front of a panel of peers and experts;
4. Be knowledgeable of the contemporary issues that are relevant to their chosen area of research.

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