CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

099. Undergraduate Research and Independent Study. (C) A maximum of 2 c.u. of CBE 099 may be applied toward the B.S.E degree requirements

An opportunity for the student to work closely with a professor in a project to develop skills and technique in research and development. To register for this course, the student writes a one-page proposal that is approved by the professor supervising the research and submitted to the undergraduate curriculum chairman during the first week of the term.

111. Modern Engineering Problem Solving. (A)

The application of computer tools to engineering problem solving.

150. Introduction to Biotechnology. (A) Prerequisite(s): Reserved for Freshmen only.

The goal of this course is to teach you the fundamentals of biotechnology and introduce you to concepts in Chemical Engineering along the way. Concepts in Biotechnology that will be covered include, DNA, RNA, the Central Dogma, proteins, recombinant technology, RNA silencing, electrophoresis, chromatography, synthetic biology, pull down assays, PCR, hybridization, array technology, DNA machines, DNA sequencing, and forensics. Concepts in Chemical Engineering that will be covered include the mass balance, scaling laws and the Buckingham-Pi theorem, kinetics of enzyme reactions, thermodynamics of molecular binding, the Langmuir isotherm, separations via chromatography.

160. Introduction to Chemical Engineering. (B)

Students will learn to read and understand a process flow sheet. There is a focus on drawing a process flow sheet, and formulating and solving the material balances for the chemical processes involving chemical reactions (some with recycle streams, some with purge streams, and some with bypass streams). Additionally, students will understand the limits of the ideal gas law, and have a working knowledge of the cubic equations of state and the concept of a compressibility factor. The class will study the basic concepts of gas-liquid phase equilibrium and apply Raoult's Law to solve phase equilibrium problems. A final objective is to design flow sheets and solve material balances for simple chemical processes using ASPEN (chemical engineering simulation program).

L/R 230. Material and Energy Balances of Chemical Processes. (A) Prerequisite(s): CBE 160, Sophomore standing.

Analysis of processes used in the chemical and pharmaceutical industries. Mass and energy balances, properties of pure fluids, equations of state. Heat effects accompanying phase changes and chemical reactions.

L/R 231. Thermodynamics of Fluids. (B) Holleran.Prerequisite(s): CBE 230.

Students will understand, evaluate, and apply different equations of state relating pressure, temperature, and volume for both ideal and non-ideal systems. The course will focus on calculating and applying residual properties and departure functions for thermodynamic analysis of non-ideal gases. Students will apply and describe simple models of vapor-liquid equilibrium in multi-component systems (e.g. Raoult's Law, modified Raoult's Law, Henry's Law). Additionally, the class will analyze and describe properties of non-ideal mixtures and their component species. We will also model and predict reaction equilibria (including non-ideal fluid systems), as well as solve problems related to complex phase equilibria of multi-component systems (find equilibrium compositions for non-ideal phases).

296. Study Abroad.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

297. Study Abroad. (C)

L/R 350. Fluid Mechanics. (A) Hollaran.Prerequisite(s): CBE 231.

This course is designed for students to understand the fundamental characteristics of fluids. We will develop, starting from first principles, the basic equations for fluid statics, and use them to assess buoyancy forces and determine the pressure variations in fluids with rigid body rotation. Students will understand in detail the basic types of fluid flow line patterns (eg. streamlines and streamtubes) and the different types of interchangeable energy forms (eg. kinetic, potential, and pressure). It is also important to develop, starting from first principles, the formulations for inviscid and viscous flow problems. These include the discussion of a control system and system boundaries, the detailed construction of conservations equations of mass, energy, and momentum for Newtonian fluids, the derivation of the Navier-Stokes equations, and the determination of appropriate initial and boundary conditions. A final objective of the course is to solve various fluid mechanics problems using control systems, dimensional analysis, and developed equations. Such problems include, but are not limited to, the terminal velocity of a falling sphere, Stokes flow, the relation between the friction factor and the Reynolds number, and flow profiles in numerous geometries.

L/R 351. Heat and Mass Transport. (B) Prerequisite(s): CBE 350.

Steady-state heat conduction. The energy equation. Fourier's law. Unsteady-state conduction. Convective heat transfer. Radiation. Design of heat transfer equipment. Diffusion, fluxes, and component conservation equations. Convective mass transfer. Interphase mass transport coefficients.

L/R 353. Advanced Chemical Engineering Science. (A) Prerequisite(s): CBE 231.

Applications of physical chemistry to chemical engineering systems. Equilibrium statistical mechanics of ideal gases, dense fluids and interfacial phases. Chemical reaction rates. Collision and transition state theories. Heterogeneous catalysis. Electronic structure and properties of solids.

371. Separation Processes. (B) Prerequisite(s): CBE 231.

The design of industrial methods for separating mixtures. Distillation; liquid-liquid extraction; membranes; absorption. Computer simulations of the processes.

375. Engineering and the Environment. (B) Prerequisite(s): Sophomore Standing.

The principles of green design, life cylce analysis, industrial ecology, pollution prevention and waste minimization, and sustainable development are introduced to engineers of all disciplines as a means to identify and solve a variety of emerging environmental problems. Case studies are used to assess the problems and devise rational solutions to minimize environmental consequences.

L/R 400. Introduction to Product and Process Design. (A) Prerequisite(s): CBE 351, 371. Corequisite(s): CBE 451.

Molecular-structure design, process synthesis, steady-state and batch simulation, second-law analysis, heat integration, equipment sizing, and capital cost estimation.

410. Chemical Engineering Laboratory. (A) Prerequisite(s): CBE 351, 371.

Experimental studies in heat and mass transfer, separations and chemical reactors to verify theoretical concepts and learn laboratory techniques. Methods for analyzing and presenting data. Report preparation and the presentation of an oral technical report.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

430. (CBE 510, MSE 430) Polymers and Biomaterials. (B) Prerequisite(s): MSE 260 or equivalent course in thermodynamics or physical chemistry (such as BE 223, CBE 231, CHEM 221, MEAM 203).

Polymer is one of the most widely used materials in our daily life, from the rubber tires to clothes, from photoresists in chip manufacturing to flexible electronics and smart sensors, from Scotch tapes to artificial tissues. This course teaches entry-level knowledge in polymer synthesis, characterization, thermodynamics, and structure-property relationship. Emphasis will be on understanding both chemical and physical aspects and polymer chain size/dimension that drive the molecular, microscopic and macroscopic structures and the resulting properties. We will discuss how to apply polymer designs to advance nanotechnology, electronics, energy and biotechnology. Case studies include thermodynamics of block copolymer thin films and their applications in nanolithography, shape memory polymers, hydrogels, and elastomeric deformation and applications.

L/R 451. Chemical Reactor Design. (A) Prerequisite(s): CBE 231 and CBE 351.

Design of reactors for the production of chemical products. Continuous and batch reactors. Chemical kinetics. Effects of back-mixing and non-ideal flow in tubular reactors. Heterogeneous reactions. Construction and economic analysis of reactors.

L/R 459. Product and Process Design Projects. (B) Prerequisite(s): CBE 400.

Design of chemical, biochemical, and materials products and processes based on recent advances in chemical and bioengineering technology. Design group weekly meetings with faculty advisor and industrial consultants. Comprehensive design report and formal oral presentation. Heat exchanger design and profitability analysis.

L/R 460. Chemical Process Control. (B) Prerequisite(s): CBE 353.

Dynamics and control of linear single-input, single output (SISO) systems in chemical processes. Laplace transforms. Dynamic responses of linear systems to inputs in time and transform domains. Frequency domain analysis. Feedback control strategies. Stability. Controller tuning. Advanced control, including cascade and feed forward control. Introduction to multiple-input, multiple-output (MIMO) control.

L/R 479. Biotechnology and Biochemical Engineering. (A) Prerequisite(s): Junior/Senior Standing in Engineering and CBE 150 or Permission of the Instructor.

An overview of several important aspects of modern biotechnology from a chemical engineering perspective: DNA, enzymes, proteins, molecular genetics, genetic engineering, cell growth kinetics, bioreactors, transport processes, protein recovery and protein separations. Group projects include a MATLAB project and a pharmaceutical profile.

480. Laboratory in Biotechnology and Genetic Engineering. (B) Prerequisite(s): CBE 479 or Permission of the Instructor.

The laboratory methods in biochemical and genetic engineering learned include molecular cloning techniques, cell transformation, DNA gel electrophoresis, ImageJ, PCR, DNA sequencing, SDS-PAGE, Western Blot, and enzyme assays. Culture techniques for bacteria, yeast and animal cells are taught and practiced. The students write several individual lab reports during the semester. A group presentation and report on a proposal for a new lab experiment is the final assignment for the lab.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

508. Probability and Statistics for Biotechnology. (L)

This course is designed as an overview of probability and statistics including linear regression, correlation, and multiple regression. The program will also include statistical quality control and analysis of variance with attention to method of analysis, usual method of computation, test on homogeneity of variances, simplifying the computations, and multi-factor analysis.

521. Fundamentals of Industrial Catalytic Processes. (M)

This course will introduce students to the important concepts invovled in industrial catalytic processes. The first part of the course will review some of the fundamental concepts required to describe and characterize catalysts and catalytic reactions. The majority of the course will then focus on applying these concepts to existing heterogeneous catalysts and catalytic reactions, including discussion of the actual process design and engineering. Descriptions of some homogeneously catalyzed processes like polymerization and the synthesis of acetic acid will also be covered.

510. (CBE 430, MSE 430) Polymer Engineering. (B)

Polymer is one of the most widely used materials in our daily life, from the rubber tires to clothes, from photoresists in chip manufacturing to flexible electronics and smart sensors, from Scotch tapes to artificial tissues. This course teaches entry-level knowledge in polymer synthesis, characterization, thermodynamics, and structure-property relationship. Emphasis will be on understanding both chemical and physical aspects and polymer chain size/dimension that drive the molecular, microscopic and macroscopic structures and the resulting properties. We will discuss how to apply polymer designs to advance nanotechnology, electronics, energy and biotechnology. Case studies include thermodynamics of block copolymer thin films and their applications in nanolithography, shape memory polymers, hydrogels, and elastomeric deformation and applications.

511. Physical Chemistry of Polymers and Amphiphiles. (A)

This course deals with static and dynamic properties of two important classes of soft materials: polymers and amphiphiles. Examples of these materials include DNA, proteins, diblock copolymers, surfactants and phospholipids. The fundamental theories of these materials are critical of understanding ploymer processing, nanotechnology, biomembranes and biophysics. Special emphasis will be placedon understanding the chain conformation of polymer chains, thermodynamics of polymer chains, thermodynamics of polymer solutions and melts, dynamics of polymer and statistical thermodynamic principles of self-assembly.

520. Modeling, Simulations, and Optimization of Chemical Processes. (M)

Nonlinear systems: numerical solutions of nonlinear algebraic equations; sparse matrix manipulations. Nonlinear programming and optimization; unconstrained and constrained systems. Lumped parameter systems: numerical integration of stiff systems. Distributed parameter systems: methods of discretization. Examples from analysis and design of chemical and biochemical processes involving thermodynamics and transport phenomena.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

522. Polymer Rheology and Processing. (C) Prerequisite(s): MEAM 302 and 333 or CBE 350 and 351 or equivalent.

This course focuses on applications of rheology to polymer process technologies. It includes a general review of rheological concepts, including viscoelasticity and the influence of shear rate, temperature and pressure on polymer flow properties. The course covers the elementary processing steps common in various types of polymer manufacturing operations including handling of particulate solids, melting, pressurizing and pumping, mixing and devolatilization. Specific polymer processing operations including extrusion, injection molding, compression molding, fiber spinning and wire coating are covered. Emerging polymer processing applications in microelectronics, biomedical devices and recycling are also discussed.

525. Molecular Modeling and Simulations. (A) Prerequisite(s): CBE 231 or 618 or equivalent background in physcial chemistry.

Students will explore current topics in thermodynamics through molecular simulations and molecular modeling. The requisite statistical mechanics will be conveyed as well as the essential simulation techniques (molecular dynamics, Monte Carlo, etc.). Various approaches for calculating experimentally measurable properties will be presented and used in student projects.

535. Interfacial Phenomena.. (C)

This course provides an overview of fundamental concepts in colloid and interface science. Topics include the thermodynamics of interfaces, interfacial interactions (e.g. van der Waal's interactions, electrostatics, steric interactions), adsorption, the hydrodynamics and stability of interfacial systems, self assembly, etc. Connections to self-assembly and directed assembly of nanomaterials and emerging topics are explored. Pre-requisites: undergraduate thermodynamics, some familiarity with concepts of transport phenomena (including fluid flow and mass transfer) and differential equations

L/R 540. (BE 540) Biomolecular and Cellular Engineering. (C)

This course will introduce concepts and methods for the quantitative understanding of molecular and cellular phenomena. Topics include molecular recognition, receptor-ligand binding, viral infection, signal transduction, cell adhesion, motility, and cytoskeletal dynamics. The course requires mathematics at the level of differential equations, and some knowledge of Matlab programming. A basic knowledge of cell biology is suggested, although not required.

541. (BE 541) Engineering and Biological Principles in Cancer. (B) Prerequisite(s): Senior standing or permission of the instructor.

This course provides an integrative framework and provides a quantitative foundation for understanding molecular and cellular mechanisms in cancer. The topics are divided into three classes: (1) the biological basis of cancer; (2) cancer systems biology; and (3) multiscale cancer modeling. Emphasis is placed on quantitative models and paradigms and on integrating bioengineering principles with cancer biology.

543. Sust Dev/Water Res Sys. (B)

The application of systems methodology to the design of water supply and sanitation projects. The focus is on the designing for sustainability by emphasizing how technical solutions fit within the appropriate social context. Case studies are used to demonstrate these principles across a range of examples from developed and developing countries.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

554. (BE 554) Engineering Biotechnology. (B)

Advanced study of re DNA techniques; bioreactor design for bacteria, mammalian and insect culture; separation methods; chromatography; drug and cell delivery systems; gene therapy; and diagnostics.

545. Electrochemical Energy Conversion and Storage. (C) Prerequisite(s): Introductory chemistry and an undergraduate course in thermodynamics (e.g. CBE 231, MEAM 203).

Fuel cells, electrolysis cells, and batteries are all electrochemical devices for the interconversion between chemical and electrical energy. These devices have inherently high efficiencies and are playing increasingly important roles in both large and small scale electrical power generation, transportation (e.g. hybrid and electric vehicles), and energy storage (e.g. production of H2 via electrolysis). This course will cover the basic electrochemistry and materials science that is needed in order to understand the operation of these devices, their principles of operation, and how they are used in modern applications.

546. Fundamentals of Industrial Catalytic Processes. (B)

A survey of heterogeneous catalysis as applied to some of the most important industrial processes. The tools used to synthesize and characterize practical catalysts will be discussed, along with the industrial processes that use them.

L/R 552. (BE 552) Cellular Bioengineering. (B)

Application of chemical engineering principles to analysis of eukaryotic cell biological phenomena, emphasizing receptor-mediated cell function. Topics include receptor/ligand binding kinetics and trafficking dynamics, growth factor regulation of cell proliferation, cell adhesion, cell migration and chemotaxis, and consequences of these in physiological situations such as the immune and inflammatory responses, angiogenesis, and wound healing.

L/R 555. (BE 555, MEAM555) Nanoscale Systems Biology. (A) Discher.Prerequisite(s): Background in Biology, Chemistry or Engineering with coursework in thermodynamics or permission of the instructor.

From single cell manipulations down to studies of single nanoparticles and single molecules, basic cell- molecular biology and biotechnologies are increasingly 'nano' as well as quantitative. Lectures and laboratories in this course start with nano aspects of optical detection, address the basic thermodynamics of biomolecular interactions, and then cover genomic scale devices. Nanoprobe methods are then complemented by basic theories of self-assembly and polymers as well as application in drug delivery and virus engineering with analyses of limitations imposed by the innate immune system. Skills in analytical and professional presentations, papers and laboratory work will be developed.

L/R 557. Stem Cells, Proteomics and Drug Delivery - Soft Matter Fundamentals. (B) Prerequisite (s): Background in Biology, Chemistry or Engineering.

Lectures on modern topics and methods in cell and molecular biology and biomedicine from the perspective of soft matter science and engineering. Discussions and homeworks will cover soft matter related tools and concepts used to 1) isolate, grow, and physically characterize stem cells, 2) quantify biomolecular profiles, 3) deliver drugs to these cells and other sites (such as tumors with cancer stem cells) will be discussed. Skills in analytical and professiona presentations, papers and laboratory work will be developed.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

560. Biomolecular Engineering. (M)

This course will cover current state of the art in engineering approaches to design, optimization, and characterization of biomolecules. Particular emphasis will be placed on proteins. Fundamental physical biochemistry of biological macromolecules will be reviewed to provide a basis for understanding approaches to de novo protein design, combinatorial directed evolution, methods for analysis of structure and function, and practical applications for this class of molecules. Much of the course material will be drawn from the current literature.

562. (BE 562) Drug Discovery and Development. (A)

Part A. Intro to Drug Discovery; Overview of Pharmaceutical Industry and Drug Development Costs, Timelines; High Throughput Screening (HTS): Assay Design and Sensitivity Solid Phase Synthesis and Combinatorial Chemistry; Enzyme Kinetics; Fluorescence, Linearity, Inner-filter effect, quenching; Time dynamics of a Michaelis-Menton Reaction; Competitive Inhibitor; FLINT, FRET, TRF, FP, SPA, alpha-screen; Enzyme HTS (protease); Cell based screening; Fura-2 ratio, loading signaling; Gfpcalmodulin-gfp integrated calcium response; Estrogen/ERE-Luc HTS; Problems with cell based screening (toxicity, permeability, nonspecificity); Instrumentation, Robotics/Automation; Z-factor; SAR, Positioning Scanning; Microarray HTS; IC50, % Conversion in HTS and IC50, Assay Optimization.

Part B. New drug development and regulatory compliance related to small molecules and biologics, overview of biopharma industry, regulation and development process for new chemical entities and biolgies, formulation of pharmaceutical dosage forms, current Good Manufacturing Practices, chemistry manufacture and controls, overview of Common Technical Document (CTD), managing post-approval changes - formulatin, process, packaging, and analytical.

563. Dev & Manuf of Biopharm.. (C)

New drug development and regulatory compliance related to small molecules and biologics, overview of biopharma industry, regulation and development process for new chemical entities and biolgies, formulation of pharmaceutical dosage forms, current Good Manufacturing Practices, chemistry manufacture and controls, overview of Common Technical Document (CTD), managing post-approval changes - formulatin, process, packaging, and analytical.

597. Master's Thesis Research. (C)

564. (PHRM564) Drug Delivery.. (C)

Students will learn about drug distribution throughout the body, pharmacokinetics, nanoparticle systems for drug delivery, gene delivery systems, targeted drug delivery translation of new drug delivery systems to patients, and case studies on current drug delivery systems in research. Faculty from engineering and medicine will give lectures on their research interests. The students read current journal articles throughout the course. A major assignment for the course is a written and oral group proposal on a topic chosen by the students that is relevant to the course material.

580. Masters Biotech Lab.. (C) Reserved for students in the Master of Biotechnology Program

In this course, students will learn biochemical and genetic engineering laboratory skills including molecular cloning techniques, cell transformation, DNA gel electrophoresis, ImageJ, PCR, DNA sequencing, SDS-PAGE, Western blot and enzyme assays. Cell culture techniques for bacteria, yeast and animal cells will be taught and practiced. The students write several individual lab reports during the semester. A group presentation and report on a proposal for a new lab experiment is the final assignment for the lab.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

L/R 582. (BE 557) From Cells to Tissue: Engineering Structure and Function. (B)

The goal of this course is to introduce students to engineering concepts in understanding and manipulating the behavior of biological cells. We will try to understand the interplay between cells,their extracellular microenvironment, and intracellular signaling pathways in regulating cellular and multicellular structure and function. In particular, we will explore the use of modern experimental approaches to characterize and manipulate cells for bioengineering applications, and the concepts in scaling cellular engineering functional tissues. In this context, we will focus on several topics, including signal transduction and the molecular regulation of cell function, cellular microenvironment, cell adhesion and mechanics, stem cells, multicellularity, and experimental models of tissue develpment.

599. Master's Indep Study. (C)

L/R 602. Statistical Mechanics of Liquids. (C) Prerequisite(s): Graduate level course in statistical mechanics (e.g. CBE 618, MSE 575, BE 619, BMB 604, PHYS 581, CHEM 521). An advanced statistical mechanics course (e.g., PHYS 611, CHEM 522) is recommended, but not required.

The course will focus on advanced concepts and methods in statistical mechanics with a particular emphasis on the liquid state, e.g. aqueous solutions, capillarity, polymers, colloids, glasses, amphiphilic self-assembly, etc. Principles of both equilibrium and non-equilibrium statistical mechanics will be discussed and connections to experimentally measurable quantities will be made wherever possible.

617. (ESE 617, MEAM613) Control of Nonlinear Systems. (A)

PID control of nonlinear systems; steady-state, periodic and chaotic attractors. Multiple-input, multiple-output systems; decoupling methods and decentralized control structures. Digital control; z-transforms, implicit model control, impact of uncertainties. Constrained optimization; quadratic dynamic matrix control. Nonlinear predictive control. Transformations for input/output linearized controllers.

L/R 618. (BE 662, MEAM662) Advanced Molecular Thermodynamics. (A)

Review of classical thermodynamics. Phase and chemical equilibrium for multicomponent systems. Prediction of thermodynamic functions from molecular properties. Concepts in applied statistical mechanics. Modern theories of liquid mixtures.

619. Application of Thermodyanics to Chemical Engineering II. (M)

An introduction to statistical mechanics and its applications in chemical engineering. Ensembles. Monatomic and polatomic ideal gases. Ideal lattices; adsorption and polymer elasticity. Imperfect gases. Dense liquids. Computer simulation techniques. Interacting lattices.

621. Advanced Chemical Kinetics and Reactor Design. (A)

Mechanisms of chemical reactions. Transition state theory. Langmuir-Hinshelwood Kenetics. Absorption and cataysis. Simple and complex reaction schemes. Design of idealized reactors. Fluidized reactors. Solid-gas reactions. Residence time distributions. Reaction and diffusion in solid catalysts. Reactor stability and control.

CHEMICAL AND BIOMOLECULAR ENGINEERING (EG) {CBE}

L/R 640. (MEAM570) Transport Processes I. (A)

The course provides an unified introduction to momentum, energy (heat), and mass transport processes. The basic mechanisms and the constitutive laws for the various transport processes will be delineated, and the conservation equations will be derived and applied to internal and external flows featuring a few examples from mechanical, chemical, and biological systems. Reactive flows will also be considered.

641. Transport Processes II (Nanoscale Transport). (B)

A continuation of CHE 640, with additional emphasis on heat and mass transport. This course aims to teach transport concepts and methods useful in many current CBE laboratory settings. The emphasis will be on microscopic dynamics and transport in both hard and soft systems (e.g. colloids and polymers), of relevance to a variety of biological and biomolecular systems. Wherever possible, will make connections between classical, macroscopic transport, and what is happening microscopically. Will make use of a comination of analytic and algorithmic/numerical methods to facilitate understanding of the material. Physical topics will include stochastic, "single-molecule", non-ideal, hard sphere and frustrated systems, phase transitions, non-equilibrium statistical mechanics and optics. Concepts will include properties of stochastic functions (Gaussian statistics, correlation functions and power spectra), Fourier methods, Convolution, the Central Limit theorem, anomalous diffusion, percolation, and the Fluctuation/Dissipation theorem. Computational methods will concentrate on Monte Carlo simulations of "toy" models.

737. Biotechnology Seminar. (M)

700. Special Topics. (M)

Lectures on current research problems or applications in chemical engineering. Recent topics have included heat transfer, polymer science, statistical mechanics, and heterogeneous catalysis.

701. Scattering Methods/Colloidal and Macromolecular Systems. (M)

The scattering of light, x-rays and neutrons in (1) the characterization of macromolecules in solution and the solid state, (2) the study of solid-state polymer morphology, and (3) the characterization of inorganic, organic and biological systems of colloidal dimensions. Both theory and experimental methods will be covered.

702. Surface Science. (M)

Techniques in surface science. Surface characterization techniques. Applications to MOCVD, surface chemistry, and surface physics.

899. Independent Study. (C)

990. Masters Thesis. (C)

995. Dissertation. (C)

999. Thesis/Dissertation Research. (C)

For students working on an advanced research program leading to the completion of master's thesis or Ph.D. dissertation requirements.