GRADUATE COURSES APPROVED FOR FULFILLING COURSE REQUIREMENTS FOR THE PHD and MS DEGREES

All 500-level courses and above from CHBE are approved.

The following is a list of all courses outside the department that have been taken by our graduate students and have been approved by the Graduate Studies Committee (GSC) to count towards fulfilling the course requirements toward a PhD degree. In an effort to continuously update this list and in case you wish to take a course not included in the following, we ask you to complete the CHBE Course Approval Request Form. This form can be found at chbe@rice.edu. Graduate/Forms.

BIOCHEMISTRY AND CELL BIOLOGY		
BIOC 530	Lab Module in NMR Spectroscopy and Molecular Modeling	The students will learn to set up, acquire, and process one-dimensional and basic two-dimensional NMR experiments. Spectral interpretation (resonance assignment and extraction of structural information) for nucleic acids and proteins using homonuclear and heteronuclear data will be performed. Enrollment limited to 12, with priority to graduate students. Offered first half of the semester. BIOC 352 may be taken concurrently with BIOC 530. College: School of Natural Sciences **Department:** Biosciences Pre-requisites: BIOS 352 OR BIOC 352 or permission of instructor
BIOC 535	Practical X-Ray Crystallography	This is an introduction to macromolecular crystallography with emphasis on crystallization methods, data acquisition, processing and molecular model-building. Approaches to solving structures will be discussed, as well as refinement of molecular models. Offered second half of the semester. College: School of Natural Sciences **Department:** Biosciences
BIOC 543	Secondary Metabolism	A survey of the biosynthetic pathways leading to the major classes of natural products. Topics covered include the use of radioactive and stable isotopes, the synthesis of labeled organic compounds, mechanistic investigations of secondary metabolic enzymes, and the cloning and characterization of secondary metabolic genes. Cross-list: CHEM 543. College: School of Natural Sciences **Department:** Biosciences Pre-requisites: CHEM 212
BIOC 545	Advanced Molecular Biology and Genetics	Molecular and genetic aspects of the regulation of gene expression as seen in simple prokaryotic systems and the model eukaryotic systems used for studies of development. College: School of Natural Sciences **Department:** biosciences Pre-requisites: (BIOS 201 OR BIOC 201) AND (BIOS 202 OR EBIO 202) AND (BIOS 301 OR BIOC 301) AND (BIOS 344 OR BIOC 344) AND (BIOS 341 OR BIOC 341) or permission of instructor

BIOC 550	Viruses & Infectious Diseases	Animal viruses, especially those relevant to human health, will be discussed. Topics primarily focus on virus structure and the molecular biology of the virus life cycle. Practical issues such as the history of viral diseases, clinical manifestations, laboratory diagnosis, management and prevention will also be discussed. Department: Biosciences Pre-requisite(s): BIOC 201 AND BIOC 301 AND BIOC 341 or permission of instructor College: School of Natural Sciences **Department:** Biosciences
BIOC 551	Molecular Biophysics	Focus on principles of common biophysical methods used for study of conformations and dynamics of biological macromolecules and assemblies. Topics cover spectroscopic methods (absorption, fluorescence, circular dichroism, epr, NMR), transport processes, sedimentation, calorimetry, mass spectrometry, crystallography, cryo-electron microscopy, atomic force microscopy, ligand-protein interactions, protein folding, single molecule detection, computer simulations, functional genomics and laboratory evolution. Biological examples will be used to demonstrate merits and complementarity in each of the biophysical methods. Graduate/Undergraduate Equivalency: BIOC 481. Instructor permission required College: School of Natural Sciences **Department:** Biosciences
BIOC 571	Bioinformatics: Network Analysis	This course covers computational aspects of biological network analysis, a major theme in the area of systems biology. The course addresses protein-protein interaction networks, signaling, and metabolic networks, and covers issues related to reconstructing, analyzing, and integrating various types of networks. Cross-list: BIOE 564, COMP 572. Department: Biosciences. College: School of Natural Sciences **Department:** Boisciences
BIOC 583	Molecular Interactions	First of two integrated classes taken by first-year graduate students in BCB (to be followed by BIOC 588, Cellular Interactions). Covers advanced topics in biochemistry, ranging from protein and nucleic acid synthesis, folding, function, and engineering to allostery, dynamics, and degradation with an emphasis on fundamental principles, research methodologies, problem solving, and critical analysis of primary literature. Enrollment limited to BCB graduate students. Open only to BCB graduate students. College: School of Natural Sciences **Department:** Biosciences
BIOC 585	Fundamentals of Cellular and Molecular Neuroscience	Cellular, molecular, and integrative mechanisms of neural function, including membrane and axon physiology, synaptic transmission and plasticity, sensory transduction and processing. Graduate/Undergraduate Equivalency: BIOC 385. College: School of Natural Sciences **Department:** Biosciences
BIOC 589	Computational Molecular Bioengineering/ Biophysics	This is a course designed for students in computationally-oriented biomedical and bioengineering majors to introduce the principles and methods used for the simulations and modeling of macromolecules of biological interest. Protein conformation and dynamics are emphasized. Empirical energy function and molecular dynamics calculations, as well as other approaches, are described. Specific biological problems are discussed to illustrate the methodology. Cross-list: BIOE 589. College: School of Natural Sciences **Department:** Biosciences

BIOENGINEERING		
BIOE 507	Systems Biology of Blood Vessels	How blood vessels respond to hypoxia is a process critical to the progression of many diseases and conditions including cardiovascular disease, cancer, cerebrovascular disease, diabetes, obesity and arthritis. Physiological processes such as exercise, aging, and wound healing also depend on hypoxia-induced microvessel changes. This course introduces concepts of hypoxic response, angiogenesis, and capillary remodeling - from the effects at the intracellular level to the whole body. Topics covered include computational systems biology modeling of hypoxia and angiogenesis, the use of angiogenesis in tissue engineering and regenerative medicine, imaging of blood vessel dynamics, capillaries of the brain, and the design of new blood vessels. Graduate students will be required to complete a term research project and present a related short seminar. Graduate/Undergraduate Equivalency: BIOE 307. College: School of Engineering Department: Bioengineering Pre-requisites: MATH 381
BIOE 508	Sythentic Biology	Design of biology at scales from molecules to multicellular organisms will be covered by lecture, primary literature, and student presentations. Students will write a research proposal at the end of the course. Cross-list: SSPB 503, Graduate/Undergraduate Equivalency: BIOE 408. College: School of Engineering Department: Bioengineering Pre-requisities: BIOE 332
BIOE 516	Mechanics, Transport and Cellular Signaling	This course will cover the fundamental principles of mechanics, thermodynamics, and transport in the context of classical and contemporary bioengineering problems. An overall goal will be to expose students to the integrated approaches that are necessary to solve complex research problems. Topics covered will include membrane transport, cell signaling, and mechanotransduction. Department permission required College: School of Engineering Department: Bioengineering
BIOE 517	Instrument/ Molecular Analysis	This course will cover the basic principles of optics, optical instrumentation, microscopy and molecular detection technologies. Emphasis will be placed on the application of advance microscopy techniques to imaging problems in biology and medicine. Department permission required College: School of Engineering Department: Bioengineering
BIOE 521	Microcontroller Applications	This class covers the usage of microcontrollers in a laboratory setting. We will start with basic electronics and, in the lab component, design, program, and build systems utilizing widely-available microcontrollers (e.g. Arduino, Raspberry Pi). Units in motion control, sensors (light, temperature, humidity, UV/Vis absorbance), and actuation (pneumatics, gears, and motors) will provide students with functional knowledge to design and prototype their own experimental systems for laboratory-scale automation. BIOE 521 students will be expected to complete a final research paper. Graduate/Undergraduate Equivalency: BIOE 421. Instructor permission required College: School of Engineering Department: Bioengineering Pre-requisite(s): BIOE 385

BIOE 522	Gene Therapy	This course will examine the gene therapy field, with topics ranging from gene delivery to vectors to ethics of gene therapy. The design principles for engineering improved gene delivery vectors, both viral and nonviral, will be discussed. The course will culminate in a design project focused on engineering a gene delivery device for a specific therapeutic application. Graduate/Undergraduate Equivalency: BIOE 422. College: School of Engineering Department: Bioengineering Pre-requisites: CHEM 212 AND (BIOS 201 OR BIOC 201) or permission of instructor
BIOE 523	Control Theory/ Synthetic Bio	An overview of the interplay between control theory and systems/synthetic biology. Topics include introduction to basic control theory and methods and tools for analyzing the dynamics of biological systems. College: School of Engineering Department: Bioengineering
BIOE 540	Introduction to Systems Biology and Systems Biotechnology	Systems biology is an integrated experimental and mathematical approach to study the complex dynamic interactions between various componenets of a biological system. The course is designed to explore the basic concepts of systems biology. The course will introduce "systems" approaches based on genomics, transcriptomics, proteomics and metabolomics. College: School of Engineering Department: Bioengineering
BIOE 543	DNA Biotechnology/ Biophysics, and Modeling	Semester-long course on fundamental properties of DNA, and their role in DNA biotechnology. Students will develop, analyze, and simulate simple biophysical models of DNA reactions, as well as learn and model methods of modern DNA biotechnology. Proficiency with MATLAB required. College: School of Engineering Department: Bioengineering
BIOE 548	Machine Learning and Signal Processing for Neuro Engineering	The activity of a complex network of billions of interconnected neurons underlies our ability to sense, represent and store the details of experienced life, and enables us to interact with our environment and other organisms. Modern neuroscience techniques enable us to access this activity, and thus to begin to understand the processes whereby individual neurons enable complex behaviors. In order to increase this understanding and to design biomedical systems which might therapeutically interact with neural circuits, advanced statistical signal processing and machine learning approaches are required. This class will cover a range of techniques and their application to basic neuroscience and neural interfaces. Topics include latent variable models, point processes, Bayesian inference, dimensionality reduction, dynamical systems, and spectral analysis. Neuroscience applications include modeling neural firing rates, spike sorting, decoding, characterization of neural systems, and field potential analysis. Cross-list: ELEC 548. Department: Bioengineering

BIOE 552	Introductory Computational Systems Biology: Modeling & Design Prin. Of Biochem Networks	The course summarizes techniques for quantitative analysis and simulations of basic circuits in genetic regulation, signal transduction and metabolism. We discuss engineering approaches adapted to computational systems biology and aim to formulate evolutionary design principles explaining organization of networks in terms of their physiological demands. We discuss biochemical simulation methodology and software as well as recent advances in the field. Topics include end-product inhibition in biosynthesis, optimality and robustness of the signaling networks and kinetic proofreading. Students are expected to represent several journal articles. Same as 490 but with more emphasis on recent advances in the field - paper reading and presentations. Graduate/Undergraduate Equivalency: BIOE 490. Basic knowledge of biochemistry, cell biology, linear algebra, and ordinary differential equations is expected. College: School of Engineering Department: Bioengineering Pre-requisites: (MATH 212 OR MATH 213) AND BIOS 314
BIOE 554	Computational Fluid Mechanics	Graduate version of BIOE 454. Additional work required. Cross-list: CEVE 554, MECH 554, Graduate/Undergraduate Equivalency: BIOE 454. College: School of Engineering Department: Bioengineering
BIOE 564	Bioformatics: Network Ananlysis	This course covers computational aspects of biological network analysis, a major theme in the area of systems biology. The course addresses protein-protein interaction networks, signaling, and metabolic networks, and covers issues related to reconstructing, analyzing, and integrating various types of networks. Cross-list: BIOC 572, COMP 572. College: School of Engineering Department: Bioengineering
BIOE 576	Foundations of Biotechnology	Graduate level introduction to a wide range of research methods in biosciences and bioengineering. Individual faculty members from the Biosciences and Bioengineering will each present practices and techniques for their areas of expertise. A web-based methods database will be constructed, with student involvement, from the library of lectures. Cross-list: BIOC 576. College: School of Engineering Department: Bioengineering
BIOE 581	Cardiopul-monary Dynamics	Autonomic nervous system control of the cardiovascular and respiratory systems. Development of a large scale model of the human cardiopulmonary model used to simulate measured data from functional laboratory tests. Includes a study of instrumentation and techniques used in the cardiac catherization laboratory. A discussion of ventricular assist devices is included. The course serves as an introduction to engineering in cardiovascular diagnosis and critical care medicine. Requirements: Knowledge of ordinary differential equations; electricity and magnetism, and solid mechanics from elementary physics; linear control theory and elementary physiology of the cardio vascular and respiratory systems. Cross-list: ELEC 581. College: School of Engineering **Department:** Bioengineering Pre-requisites: ELEC 481 AND ELEC 482 AND ELEC 507

BIOE 583	Computational Neuroscience & Neural Engineering	An introduction to the anatomy and physiology of the brain. Includes basic electrophysiology of nerve and muscle. Develops mathematical models of neurons, synaptic transmission and natural neural networks. Leads to a discussion of neuromorphic circuits which can represent neuron and neural network behavior in silicon. Recommendation: Knowledge of electrical circuits, operational amplifier circuits and ordinary differential equations. Involves programming Matlab. Cross-list: ELEC 583, NEUR 583, Graduate/Undergraduate Equivalency: BIOE 481. Knowledge of basic electrical and operational amplifier circuits; and ordinary differential equations. Department: Bioengineering
BIOE 589	Computational Molecular Bioengineering/ Biophysics	This is a course designed for students in computationally-oriented biomedical and bioengineering majors to introduce the principles and methods used for the simulations and modeling of macromolecules of biological interest. Protein conformation and dynamics are emphasized. Empirical energy function and molecular dynamics calculations are described. Specific biological problems are discussed to illustrate the methodology. Classic examples such as the cooperative mechanism of hemoglobin and more frontier topics such as the motional properties of molecular motors and ion channels as well as results derived from the current literature are covered. Cross-list: BIOC 589. Recommended prerequisite(s): MATH 212, BIOS 301, BIOE 332. College: School of Engineering Department: Bioengineering
BIOE 590	Introduction to Neuroengineering: Measuring and Manipulating Neural Activitiy	Neuroengineering is an emerging discipline focused on measuring and manipulating the activity of the brain and nervous system. Using the language of physics and engineering, this course serves as an introduction to neuroengineering to students who may have little or no prior biology training. The course begins by describing how ion channels, membrane potentials, action potentials, and synapses represent information within the brain. Students will then learn a variety of techniques to model this behavior, and modern methods to measure and manipulate neural activity using electrical, optical, and genetic techniques. Students will be expected to be familiar with voltage, current, resistance, capacitance, RC circuits, and statistical mechanics. Homework assignments will require the use of Matlab. Additional coursework required beyond the undergraduate course requirements. **Department:** Bioengineering
BIOE 615	Bioengineering and Cardiac Surgery	This course will address biomaterials and medical devices relevant to cardiac and vascular surgery and interventional cardiology in adult and pediatric patients. Mechanical and design considerations, notable successes and failures, and ethical issues will also be discussed, as will differences in cardiac disease and care due to health disparities. College: School of Engineering Department: Bioengineering
BIOE 631	Biomaterials Engineering	Emphasis will be placed on issues regarding design and synthesis of materials to achieve specific properties and biocompatibility. An overview of significant biomaterials application will be given, including topics such as ophthalmic biomaterials, orthopedic applications, cardiovascular biomaterials, and drug delivery systems. Regulatory issues concerning biomaterials will also be addressed. Graduate/Undergraduate Equivalency: BIOE 431. College: School of Engineering Department: Bioengineering Pre-requisites: (CHEM 211 OR CHEM 251) AND (BIOS 201 OR BIOC 201) OR BIOE 370 or permission of instructor

BIOE 661	Oncology for Bioengineers: Molecules to Organs	Students will work through a series of patient cases that present foundational oncology concepts for graduate bioengineering and biomedical science students interested in cancer-related translational research. The class will use collaborative problem-based learning to evaluate risk factors, epidemiology, prevention, screening and detection, clinical signs and symptoms, staging and grading, management, and clinical trials for a variety of cancers. Emerging research findings and their clinical and engineering applications will be emphasized. Students will review and collaboratively discuss each case, decide on relevant learning issues, gather information, present findings for further review and discussion, and submit a case-specific written assignment. Using the same model, each student will then develop and lead his/her own patient case for class study. Required: Admission to Med Into Grad Program. Instructor permission required College: School of Engineering Department: Bioengineering
COMPUTATIONAL AND APPLIED MATHEMATICS		
CAAM 453	Numerical Analysis I	Construction and analysis of numerical algorithms for root finding, interpolation and approximation of functions, quadrature, and the solution of differential equations; fundamentals of computer arithmetic; solution of linear systems, least squares problems, and eigenvalue problems via matrix factorizations; the singular value decomposition (SVD) and basic sensitivity analysis. Computer programming in MATLAB is required. Credit may not be received for both CAAM 453 and CAAM 553. Recommended Prerequisite(s): CAAM 335. College: School of Engineering Department: Comp. & Applied Mathematics
CAAM 501	Analysis I	Real numbers, completeness, sequences and convergence, compactness, continuity, the derivative, the Riemann integral, fundamental theorem of calculus. Vector spaces, dimension, linear maps, inner products and norms. Credit may not be received for both CAAM 401 and CAAM 501. Instructor permission required Department: Computational & Applied Math
CAAM 508	Nonlinear Systems: Analysis and Conrol	Mathematical background and fundamental properties of nonlinear systems: Vector norms, matrix norms, matrix measures, existence and uniqueness of solutions of ordinary differential equations. Linearization, second order systems, periodic solutions, approximate methods. Lyapunov stability: Stability definitions, Lyapunov's direct method, invariance theory, stability of linear systems, Lyapunov's linearization method, converse theorems. Selected topics in nonlinear systems analysis and nonlinear control from: Input/Output stability: Small gain theorem, passivity theorem. Perturbation theory, averaging, and singular perturbations. Feedback linearization control. Other methods in the control of nonlinear systems such as backstepping, sliding mode and other Lyapunov-based design methods. Advanced nonlinear and adaptive robot control. Cross-list: ELEC 508, MECH 508. College: School of Engineering Department: Comp. & Applied Mathematics

CAAM 551	Numerical Linear Algebra	Direct methods for large, sparse linear systems; regularization of ill-conditioned least squares problems; backward error analysis of basic algorithms for linear equations and least squares, sensitivity and conditioning of linear systems and least square problems; condition estimation. Preconditioned iterative methods for linear systems (CG, GMRES, BiCGstab, QMR); multigrid methods. Matrix theory including spectral decompositions, Schur form, eigenvalue perturbation theory, and the geometry of subspaces. Eigenvalue algorithms, Sylvester and Lyapunov equations, the implicitly shifted QR algorithm, computation of the SVD, generalized eigenvalue problems. Introduction to large scale eigenvalue algorithms. Proficiency in MATLAB and acquaintance with one or more of C, F77, C++, F90 is required. College: School of Engineering Department: Comp. & Applied Mathematics Pre-requisite(s): CAAM 453 OR CAAM 553
CAAM 553	Advanced Numberical Analysis I	Construction and analysis of numerical algorithms for root finding, interpolation and approximation of functions, quadrature, and the solution of differential equations; fundamentals of computer arithmetic; solution of linear systems, least squares problems, and eigenvalue problems via matrix factorizations; the singular value decomposition (SVD) and basic sensitivity analysis. Computer programming in MATLAB is required. This course covers fewer topics than CAAM 453 with greater theoretical depth. Prerequisite CAAM 501 may be taken concurrently with CAAM 553. College: School of Engineering Department: Comp. & Applied Mathematics Pre-requisite(s): CAAM 401 OR CAAM 501
CAAM 583	Intro Random Process & Appl.	Review of basic probability; Sequences of random variables; Random vectors and estimation; Basic concepts of random processes; Random processes in linear systems, expansions of random processes; Wiener filtering; Spectral representation of random processes, and white-noise integrals. Cross-list: ELEC 533, STAT 583. College: School of Engineering Department: Comp. & Applied Mathematics
CAAM 615	Theoretical Neuroscience I: Biophysical Modeling of Cell & Circuits	Current theoretical methods used to model the properties of neurons and the processing of information by neuronal networks. Single neurons and the Hodgkin-Huxley model of action potential generation. Models of synaptic transmission. Stochastic properties of single neurons and information encoding using mean and instantaneous firing rates in visual neurons. Cross-list: NEUR 615, Graduate/Undergraduate Equivalency: CAAM 415. Department: Computational & Applied Math
CIVIL AND ENVIRONMENTAL ENGINEERING		
CEVE 520	ENVI Remediaation Restoration	Remediation principles and application of full-scale remediation technologies for restoration of contaminated soil, groundwater, and surface water. Topics include mass balances and distribution of chemicals in environmental media; development of remediation goals through risk assessment; treatment technology selection criteria and costs; groundwater, soil, and surface water restoration technologies; and regulatory considerations. Graduate students receive additional, more challenging assignments. Graduate/Undergraduate Equivalency: CEVE 420. College: School of Engineering Department: Civil and Environmental Eng

CEVE 535	Physical Chemical Processes for Water Quality Control	Principles, modeling and design aspects of physical chemical treatment processes in drinking water, wastewater and groundwater remediation applications. Modern treatment technologies such as membrane separation, advanced oxidation, and photocatalysis will be covered. College: School of Engineering Department: Civil and Environmental Eng
CEVE 536	Environmental Biotechnology and Bioremediation	Theory and application of biochemical processes in environmental engineering. Recommended prerequisite(s): CEVE 203, CEVE 401, and CEVE 402. College: School of Engineering Department: Civil and Environmental Eng
CHEMISTRY		
CHEM 501	Advanced Organic Chemistry	The principles of structure and bonding are used to explain and predict reactivity in organic chemistry. Extensive practice with reaction mechanism and curved-arrow formalism. Topics include conformational analysis, acidity/basicity, functional group preparation, stereoselective synthesis, and organo-element chemistry. Course work is different than corresponding course. Graduate/Undergraduate Equivalency: CHEM 401, CHEM 401. Department: Chemistry
CHEM 520	Classical and Statistical Thermo-dynamics	A review of the principles of classical thermodynamics and an introduction to the theories and methods of statistical thermodynamics with applications to problems in chemistry. Department: Chemistry Pre-requisite(s): CHEM 310 OR (CHEM 311 OR CHEM 312) AND MATH 212 AND (PHYS 102 OR PHYS 112)
CHEM 530	Quantum Chemistry	The purpose of this course is to provide the student with a working knowledge of the basic concepts and mathematical formalism of quantum mechanics. Topics include the mathematics of quantum mechanics, one-dimensional problems, central field problems, the harmonic oscillator, angular momentum, perturbation theory, spin, and introduction to methods of modern electronic structure theory, with applications in atomic and molecular structures, spectroscopy, and chemical bonding. Graduate/Undergraduate Equivalency: CHEM 430. Department: Chemistry Pre-requisite(s): (CHEM 310 OR CHEM 312) AND MATH 212 AND (PHYS 102 OR PHYS 112
CHEM 531	Advanced Quantum Chemistry	A hands-on approach to the methods of computational quantum chemistry and their application. College: School of Natural Sciences Department: Chemistry
CHEM 547	Supramolecular Chemistry	An examination of noncovalent interactions and their impact in biology, chemistry, and engineering. Topics will include self-assembly, molecular recognition, protein folding and structure, nucleic acid structure, polymer organization, crystallization and applications of the above for the design and synthesis of nanostructured materials. College: School of Natural Sciences Department: Chemistry
CHEM 575	Physical Methods in Inorganic Chemistry	A survey course of research techniques used in modern inorganic chemistry. Topics covered will include X-ray diffraction, matrix isolation, mass spectrometry, magnetism, electrochemistry, and various spectroscopies (IR, Raman, UV-Vis, NMR, EPR, XPS, EXAFS, and Mossbauer). Department: Chemistry

CHEM 595	Transition Metal Chemistry	Structure, bonding and reactivity of coordination and organometallic compounds; ligand field theory; electronic spectroscopy; magnetism; reaction mechanisms; catalysis. Graduate/Undergraduate Equivalency: CHEM 495. Department: Chemistry Pre-requisite(s): (CHEM 211 AND CHEM 360)
CHEM 630	Molecular Spectroscopy and Group Theory	The spectra of simple molecules, including microwave, infrared, visible, ultraviolet, and Raman spectra; introductory aspects of molecular symmetry and group theory; resonance spectroscopy; surface-enhanced spectroscopy. College: School of Natural Sciences Department: Chemistry Pre-requisities: CHEM 430
ELECTRICAL AND COMPUTER ENGINEERING		
ELEC 568	Laser Spectroscopy	Introduction to the theory and practice of laser spectroscopy as applied to atomic and molecular systems. The course covers fundamentals of spectroscopy, lasers and spectroscopic light sources, high resolution and time resolved laser spectroscopy with applications in atmospheric chemistry, environmental science and medicine. College: School of Engineering Department: Electrical & Comp. Engineering
ELEC 571	Imaging at the Nanoscale	A survey of the techniques used in imaging submicron and nanometer structures with an emphasis on applications in chemistry, physics, biology, and materials science. The course includes an introduction to scanning probe microscopy and single photon counting including STM, AFM, NSOM, and confocal microscopy, as well as discussions on the fundamental and practical aspects of image acquisition, analysis, and artifacts. College: School of Engineering Department: Electrical & Comp. Engineering
EARTH SCIENCE		
ESCI 615	Economic Geology-Petroleum	Grade Mode: Standard Letter A study of the geology of petroleum: origin, migration, and accumulation will be studied. Government regulation and industry economics will be examined. A background in sedimentary processes, stratigrapy, and structural geology are expected. Graduate/Undergraduate Equivalency: ESCI 415. Recommended Prerquisite(s): ESCI 321 and ESCI 323.
MECHANICAL ENGINEERING		
MECH 500	Advanced Mechanics of Materials	Advanced topics in solid mechanics and strength of materials including energy methods, principle of virtual work, conservation laws, constitutive modeling, aspects of elasticity theory, stability and fracture mechanics with application to the analysis and design of reliable structures. Cross-list: CEVE 500, Graduate/Undergraduate Equivalency: MECH 400. College: School of Engineering
MECH 502	Vibrations	Term project is required. Graduate/Undergraduate Equivalency: MECH 412. College: School of Engineering Department: Mechanical Engineering

MECH 508	Nonlinear Systems: Analysis and Control	Mathematical background and fundamental properties of nonlinear systems: Vector norms, matrix norms, matrix measures, existence and uniqueness of solutions of ordinary differential equations. Linearization, second order systems, periodic solutions, approximate methods. Lyapunov stability: Stability definitions, Lyapunov's direct method, invariance theory, stability of linear systems, Lyapunov's linearization method, converse theorems. Selected topics in nonlinear systems analysis and nonlinear control from: Input/Output stability: Small gain theorem, passivity theorem. Perturbation theory, averaging, and singular perturbations Feedback linearization control. Other methods in the control of nonlinear systems such as backstepping, sliding mode and other Lyapunov-based design methods. Advanced nonlinear and adaptive robot control. Cross-list: CAAM 508, ELEC 508. College: School of Engineering Department: Mechanical Engineering
MECH 517	Finite Element Analysis	An introduction to Galerkin's method and the method of least squares applied to partial differential equations. Computational considerations for efficient interpolation, numerical integration, solution and post-processing methods. Error estimation and adaptive finite element analysis. Requires the use of solid works for a student project and a supporting literature survey. Graduate/Undergraduate Equivalency: MECH 417. College: School of Engineering Department: Mechanical Engineering
MECH 519	Elasticity, Plasticity & Damage Mechanics	An overview of phenomena that determine the response of solids to deformation and loading: elasticity, plasticity, damage mechanics and cracking. Review of continuum mechanics with emphasis on the physical mechanisms of deformation and fracture. Classification of the behavior of solids. Modeling of different types of material behavior. The physics underlying the phenomena and methods for the numerical analysis of the resulting equations are discussed. Cross-list: CEVE 519. Department: Mechanical Engineering
MECH 520	Nonlinear Finite Element Analysis	Formulation and solution of nonlinear initial/boundary value problems using the finite element method. Variational principles for nonlinear problems, finite element discretization, and equation-solving strategies for discrete nonlinear equation systems. Applications include: materially nonlinear equation systems. Applications include: materially nonlinear systems, geometrically nonlinear systems, transient nonlinear problems, and treatment of non smooth constraints in a nonlinear framework. Cross-list: CEVE 503. College: School of Engineering Department: Mechanical
MECH 527	Computational Structural Mechanics and Fem	Introduction to differential and integral formulations, minimum principles, variational principles, weighted residuals, energy principles, and principle of virtual work. Boundary, initial, and eigenvalue problems. Finite element and finite difference methods for structural mechanics. Applications to static and dynamic truss beams and frame problems. MATLAB programming and use of computer software. Cross-list: CEVE 527.
MECH 554	Computational Fluid Mechanics	Additional work required. Cross-list: BIOE 554, CEVE 554, Graduate/Undergraduate Equivalency: MECH 454. College: School of Engineering Department: Mechanical Engineering
MECH 572	Aerospace Systems Engineering	Integration of engineering problem solving methodologies based on systems concepts. Applications to complex, large scale aerospace systems and problems faced by engineering managers. Recommended Pre-requisite: MECH 472 and MECH 594. College: School of Engineering Department: Mechanical Engineering

MECH 576	Structural Dynamic Systems	Introduction to structural dynamic systems and control. Linear systems and control theory, transform methods, state space methods, feedack control, observers, and identification. Applications using MATLAB. Demonstrations and laboratory examples. Students in MECH 576 will be required to do more advanced assignments and a project. Cross-list: CEVE 576. Recommended Prerequisites: (CEVE 521 or CIVI 521 or MECH 502) and (CEVE 527 or CIVI 527). College: School of Engineering Department: Mechanical Engineering
MECH 586	Respiratory System Mechanics	Mechanics of ventilation, respiratory muscle mechanics, rib cage mechanics, mechanical coupling between the respiratory muscles and the rib cage, and inferences on mechanics from respiratory muscle anatomy. The class will meet in the Pulmonary Division at Baylor College of Medicine in the Texas Medical Center. College: School of Engineering Department: Mechanical Engineering
MECH 588	Design of Mechatronic Systems	Additional work required. Graduate/Undergraduate Equivalency: MECH 488. College: School of Engineering Department: Mechanical Engineering Pre-requisites: MECH 343 AND MECH 420 AND ELEC 241
MECH 591	Gas Dynamics	Study of the fundamentals of compressible, one-dimensional gas flows with area change, normal shocks, friction, and heat addition. Includes oblique shocks, Prandtl-Meyer flows expansions, and numerical techniques. College: School of Engineering Department: Mechanical Engineering Pre-requisites: MECH 371
MECH 594	Introduction to Aerodynamics	Development of theories for the prediction of aerodynamic forces and moments acting on airfoils, wings, and bodies. Includes their design applications. College: School of Engineering Department: Mechanical Engineering Pre-requisites: MECH 371
MECH 595	Modeling Tissue Mechanics	Independent study and seminar course which focuses on modeling the mechanical properties of biological tissues. Data from experiments will be used to refine the predictions of nonlinear mathematical computer models. Aimed at juniors, seniors, and graduate students. Laboratory work performed at Baylor College of Medicine, computer work at Rice University. College: School of Engineering
MECH 596	Introduction to Flight Mechanics	This course will examine the basic flight mechanics of aircraft and spacecraft. Simulation exercises will be conducted to illustrate the principles. Recommended Pre-requisite: MECH 594 College: School of Engineering Department: Mechanical Engineering Pre-requisites: MECH 371
MECH 654	Advanced Computational Mechanics	Advanced topics in computational mechanics with emphasis on finite element methods and fluid mechanics. Stabilized formulations. Fluid-particle and fluid-structure interactions and free-surface and two-fluid flows. Interface-tracking and interface-capturing techniques, space-time formulations, and mesh update methods. Enhanced discretization and solution techniques. Iterative solution methods, matrix-free computations, and advanced preconditioning techniques. Cross-list: BIOE 654, CEVE 654. College: School of Engineering Department: Mechanical Engineering

MECH 665	Analysis of Vibrations in Nonlinear Systems	Nonlinear vibrations are studied in structural and mechanical systems. Methods for the qualitative and quantitative analysis of these systems are applied. The classification and stability of equilibrium and periodic solutions are discussed for continuous time systems and discrete maps. Floquet theory and Poincare maps are used to study periodic behavior. College: School of Engineering Department: Mechanical Engineering Pre-requisites: MECH 502
MECH 679	Applied Monte Carlo Analysis	Probability density and power spectrum based simulation concepts and procedures are discussed. Scalar and vectorial simulation are addressed. Spectral decomposition and digital filter algorithms are presented. Applications from aerospace, earthquake, marine, and wind engineering, and from other applied science disciplines are included. Cross-list: CEVE 679. College: School of Engineering Department: Mechanical Engineering
MECH 684	Radiative Heat Transfer II	Study of radiative transfer in the presence of absorbing, emitting, and scattering media. Includes combined radiation, conduction, and convection, as well as heat transfer in furnaces, fire propagation, and air pollution problems. Not offered every year. College: School of Engineering Department: Mechanical Engineering
MECH 695	Advanced Modeling Tissue Mechanics	Continuation of MECH 595/BIOE 595 with emphasis on advanced modeling the micromechanics of biological tissues. Independent study and seminar/discussion course. Data from experiments will be used to refine the predictions of mathematical models. Designed for juniors, seniors, and graduate students. Laboratory work performed at Baylor College of Medicine and computer work at Rice University. College: School of Engineering Department: Mechanical Engineering
MATERIALS SCIENCE & NANOENGINEERING		
MSNE 503	Thermodynamics & Transport Phenomena in Materials Science	Unified presentation of the kinetics and thermodynamics of mass and energy transport. Includes heterogeneous equilibrium, diffusion in solids, and heat transfer, as well as their application to engineering design. Required for materials science and engineering majors. Graduate/Undergraduate Equivalency: MSNE 401.
MSNE 506	Physical Properties of Materials	Survey of the electrical, magnetic, and optical properties of metals, semiconductors, and dielectrics based upon elementary band theory concepts. Required for materials science and engineering majors. Department : Materials Science & NanoEng
MSNE 523	Properties, Synthesis and Design of Composite Materials	Study of the science of interfaces and the properties that govern their use in composite materials. Not offered every year. The study of composite processing and methods for synthesis polymer, metal and ceramic matrix composition. Department: Materials Science and NanoEng
MSNE 533	Computational Materials Modeling	Physico-chemical principles augmented by ever-advancing computation technology have become a tool for explaining rich materials properties, designeing nano-structures and their possible functionality. This course overviews basic quantum principles of materials sturcture, and a hierarchy of approximations broadly used in computational models. This includes classical mutli-body potentials, tight-binding approximations, electronic density functional theory methods, etc. Graduate version of MSNE 433. Additional work required. Graduate/Undergraduate Equivalency: MSNE 433. Department: Materials Science and NanoEng

MSNE 535	Crystallography and Diffraction	Study of crystals by x-ray, electron and neutron diffraction. Includes basic diffraction theory as well as methods for characterizing the structure, composition and stresses in crystalline materials. Required for undergraduate materials science and engineering majors. Additional work required for graduate version. Cross-list: PHYS 535, Graduate/Undergraduate Equivalency: MSNE 435. Department: Materials Science and NanoEng
MSNE 537	Crystallography and Diffraction Lab	Selected laboratory experiments in materials science, focusing on lattice symmetry, crystallography, phase identification, and metallurgy. Required for undergraduate MSNE major. Credit may be given for only one, MSNE 537 or MSNE 437. Graduate/Undergraduate Equivalency: MSNE 437. Department: Materials Science and NanoEng
MSNE 555	Materials in Nature and Bio-Mimetic Strategies	This graduate level course will discuss the origin of several materials that exists in nature from a technology perspective and strategies to replicate them using synthetic materials processing protocols. Silicates, carbon based materials, abalone shell, bone etc. will be used to discuss the fascinating architecture developed by nature. Similarly several functional structures designed by nature such as Gecko tape and IR sensors will be discussed for designing bio-medic structure and devices. Department: Materials Science and NanoEng
MSNE 594	Properties of Polymers	The course will introduce basic concepts in polymer science including the synthesis and chemical modification of polymers as well as physical properties of polymers. Topics include approaches to polymer synthesis, processing and characterization of polymer materials, and an introduction to mathematical models applied to describe the structure and dynamics of polymeric materials. Cross-list: CHBE 594. **Department:** Materials Science and NanoEng. Pre-requisites: (CHEM 211 OR CHEM 251) AND (MATH 211 OR MATH 221)
MSNE 650	Nanomaterials and Nanomechanics	The primary goal of this course is to introduce important current developments in the field of nanomaterials and nanomechanics. The course will discuss synthesis and characteration of nanomaterials, the behaviors especially mechanical behaviors in the broad sense of such materials, and their technological applications. The basic physics and fundamental mechanisms responsible for nanoscale induced changes in properties will be stressed. **Department:** Materials Science and NanoEng
MSNE 661	Nanophotonics, Spectroscopy, and Materials for Sustainability	This course will cover the contributions that nanophotonic concepts and advance spectroscopy techniques can make to the development and characterization of novel materials for energy and sustainability. Students will cover nanophotonic concepts for novel materials and characterization techniques, ultrafast and nanoscale spectroscopy techniques, and applications in energy and sustainability. For each topic, background information will be provided about the relevant science and engineering aspects, as well as examining the state-of-the art in the topic, via student-presentations and literature reviews. Cross-list: CHEM 661, ELEC 661. Department: Materials Science & NanoEng
PHYSICS		
PHYS 510	Magnetospheric Physics	Plasma physics of the earth's magnetosphere, including interactions of the magnetosphere with the solar wind and the ionosphere. The emphasis is on large-scale phenomenon, but small scale (kinetic) physics is discussed in cases where it affects the large-scale phenomena. College: School of Natural Sciences Department: Physics
PHYS 515	Classical Dynamics	Lagrangian and Hamiltonian mechanics. College: School of Natural Sciences Department: Physics

PHYS 519	Plasma Kinetic Theory	Plasma kinetic equations (Klimontovich, Liouville, BBGKY, Balescu-Lenard, Fokker-Planck, Vlasov), Vlason theory of waves and instabilities, connections to fluid plasma models. College: School of Natural Sciences Department: Physics
PHYS 521	Quantum Mechanics I	Graduate level course on non-relativistic quantum mechanics. Topics include early quantum theory, one-dimensional systems, matrix formulation, quantum dynamics, symmetries and conservation laws, bound states, scattering, spin, and identical particles, perturbation theory. College: School of Natural Sciences Department: Physics
PHYS 522	Quantum Mechanics II	Continuation of PHYS 521. College: School of Natural Sciences Department: Physics
PHYS 526	Statistical Physics	Selected topics in statistical mechanics, including phase transitions and transport phenomena. College: School of Natural Sciences Department: Physics
PHYS 532	Classical Electrodynamics	Maxwell's equations, wave propagation, special relativity and covariant formulation, charged-particle dynamics, and radiation. College: School of Natural Sciences Department: Physics
PHYS 533	Nanostructure and Nanotech-nology I	Physics of structures and devices at the nanometer scale. After a review of solid state physics, topics include nanostructured materials, nanoelectronics, and nanomagnetism. Emphasis on relevance of nanophysics to current and future technologies. College: School of Natural Sciences Department: Physics
PHYS 534	Nanostructure and Nanotech-nology II	Physics of structures and devices at the nanometer scale. Topics include nanomechanics, bionanotechnology, advanced sensors and photonics. Continuation of PHYS 533. College: School of Natural Sciences Department: Physics
PHYS 535	Crystallography and Diffraction	Study of crystals by x-ray, electron and neutron diffraction. Includes basic diffraction theory as well as methods for characterizing the structure, composition and stresses in crystalline materials. Required for undergraduate materials science and engineering majors. Cross-list: MSCI 535. College: School of Natural Sciences Department: Physics
PHYS 537	Methods of Experimental Physics I	This two-semester course will familiarize students with basic experimental techniques that are common to all academic and industrial research laboratories. Topics will include lab safety, mechanical design, computer-based data acquisition and experimental control, laboratory electronics, vacuum technology, optics, thermal measurement and control, cryogenics and charged particle optics. College: School of Natural Sciences Department: Physics
PHYS 538	Methods of Experimental Physics II	A course to familiarize students with basic experimental techniques that are common in academic and industrial laboratories. Topic will include computer interfacing and data acquisition, charged particle optics, light optics, thermal measurement and control, and cryogenics. PHYS 537 and PHYS 538 may be taken independently of each other. College: School of Natural Sciences Department: Physics
PHYS 539	Characterization and Fabrication at the Nanoscale	Introduction to study and creation of nanoscale structures, emphasizing relevant physical principles. Techniques covered include optical, X-ray, electron-based and scanned-probe characterization, as well as patterning, deposition and removal of material. College: School of Natural Sciences Department: Physics

PHYS 542	Introduction to Nuclear and Particle Physics	Graduate/Undergraduate Equivalency: PHYS 411. College: School of Natural Sciences Department: Physics
PHYS 543	Physics of Quarks and Leptons	A continuation of PHYS 542. College: School of Natural Sciences Department: Physics
PHYS 551	Biological Physics	Introduction to biological physics. Review of basic physical concepts. Cells and their components. Diffusion and random walks. Entropy and energy concepts and their roles in biological systems. Modern experimental methods. Applications to biological macromolecules. College: School of Natural Sciences Department: Physics
PHYS 563	Introduction to Solid State Physics I	Fundamental concepts of crystalline solids, including crystal structure, band theory of electrons, and lattice vibration theory. Cross-list: ELEC 563. College: School of Natural Sciences Department: Physics
PHYS 564	Introduction to Solid State Physics II	Continuation of PHYS 563, including scattering of waves by crystals, transport theory, and magnetic phenomena. Cross-list: ELEC 564. College: School of Natural Sciences Department: Physics
PHYS 566	Surface Physics	An introduction to surface- and low-dimensional physics covering experimental surface physics and ultra-high vacuum technology, crystal structure, chemical analysis, epitaxy, nanoscale electronic and magnetic structures and devices, elementary excitations, optical properties and nanoscale sensitive magnetic and non-magnetic spectroscopies. College: School of Natural Sciences Department: Physics
PHYS 567	Quantum Materials	This course uses real data on archetypal materials to illustrate the thermodynamic and transport properties of solids, and principles of materials synthesis. The goal is building a phenomenological understanding of topics including the origin of magnetism; interactions and long range order; phase transitions (magnetism; superconductivity); quantum oscillations and Landau levels. College: School of Natural Sciences Department: Physics
PHYS 568	Quantum Phase Transitions	Introductory course for graduate students. Topics include the concepts of classical and quantum phase transitions, mean field theory, renormalization group and quantum phase transitions in magnetic, fermionic, and bosonic systems. College: School of Natural Sciences Department: Physics
PHYS 569	Ultrafast Optical Phenomena	This course covers the generation, propagation, and measurement of short laser pulses, of duration less than one picosecond. Concepts include mode locking, the effects of dispersion, optical pulse amplification, and time-domain non-linear optical phenomena. Intended as an introduction to ultrafast phenomena for graduate students or advanced undergraduates; a basic understanding of electromagnetic waves and of quantum mechanics is assumed. Cross-list: ELEC 569. College: School of Natural Sciences Department: Physics
PHYS 600	Advanced Topics in Physics	Lecture/seminars which treat topics of departmental interest. College: School of Natural Sciences Department: Physics

PHYS 605	Computational Electrodynamics and Nanophotonics	This course covers computational and numerical methods for calculating electromagnetic fields and propagation in complex geometries on the nano and microscale. Methods include the finite difference time domain method, boundary element methods, Greens functions methods, finite element methods, the discrete dipole approximation and relaxation methods. Cross-list: ELEC 605. College: School of Natural Sciences Department: Physics
PHYS 610	Biological and Molecular Simulation	Modern simulation techniques for classical atomistic systems. Review of statistical mechanical systems. Monte Carlo and molecular dynamics simulation techniques. Extensions of the basic methods to various ensembles. Applications to simulations of large molecules such as proteins. Advanced techniques for simulation of complex systems, including constraint satisfaction, cluster moves, biased sampling, and random energy models. Cross-list: BIOE 610. College: School of Natural Sciences Department: Physics Pre-requisites: CHBE 611 OR BIOE 589 OR BIOS 589 OR CHEM 520 OR PHYS 526 or permission of instructor
PHYS 622	Quantum Field Theory	An introduction to relativistic quantum field theory. Topics include: quantization of scalar, spinor, and vector fields; Feynman diagrams; gauge theories, including QED and QCD; renormalization; and functional-integral methods. College: School of Natural Sciences Department: Physics
STATISTICS		
STAT 545	GLM & Categorical Data Analysis	Contingency tables, association parameters, chi-squared tests, general theory of generalized linear models, logistics regression, loglinear models, poisson regression. College: School of Engineering Department: Statistics
STAT 552	Applied Stochastic Processes	This course covers the theory of some of the most frequently used stochastic processes in application; discrete and continuous time, Markov chains, Poisson and renewal processes, and Brownian motion. College: School of Engineering Department: Statistics Pre-requisites: STAT 431
STAT 553	Biostatistics	Same as STAT 453 with advanced problem sets. Graduate/Undergraduate Equivalency: STAT 453. College: School of Engineering Department: Statistics Pre-requisites: STAT 410 or permission of instructor
STAT 605	Statistical Computing & Grapics	Programming techniques and tools useful in advanced statistical studies. Higher level graphical methods and exploratory data analysis. STAT 605 will have more advanced assignments and examinations focusing on complex computing and graphical methods. Graduate/Undergraduate Equivalency: STAT 405. Department: Statistics
STAT 622	Bayesian Data Analysis	This course will cover Bayesian methods for analyzing data. The emphasis will be on applied data analysis rather than theoretical development. We will consider a variety of models, including linear regression, hierarchical models, and models for categorical data. Graduate/Undergraduate Equivalency: STAT 422. College: School of Engineering Department: Statistics

STAT 630	Topics in Clinical Trials	This course deals with fundamental concepts in the design of clinical studies, ranging from early dose-finding studies (phase I) to screening studies (phase II) to randomized comparative studies (phase III). The goal is to prepare the student to read the clinical trial literature critically and to design clinical studies. Additionally, the faculty will introduce newer designs for clinical studies that incorporate prior knowledge and/or satisfy optimality considerations. Topics include protocol writing; randomization; sample size calculation; study design options; interim monitoring; adaptive designs; multiple end points; and writing up the results of a clinical trial for publication. College: School of Engineering Department: Statistics
STAT 685	Environmental Statistics and Decision Making	A project oriented computer intensive course focusing on statistical and mathematical solutions and investigations for the purpose of environmental decisions. This course is required for EADM students. Graduate/Undergraduate Equivalency: STAT 485. College: School of Engineering Department: Statistics