Biomedical Engineering

BMEN 5375 (EECS 5375) Introduction to Robotics (3 semester credit hours) Fundamentals of robotics, rigid motions, homogeneous transformations, forward and inverse kinematics, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control. Prerequisites: ENGR 2300 and (EE 4310 or BMEN 4310 or MECH 4310) or equivalent. Lab fee of $30 required. (2-3) Y

BMEN 6201 (BMEN 7201) Career Development Skills for Biomedical Engineers MS (2 semester credit hours) Biomedical Engineering as a field requires a wide range of skills not traditionally taught in the classroom or lab, including self-presentation, collaboration, and science communication. This course bridges this knowledge gap through interactive training and assignments, and helps students to develop a career plan to help guide them to the most useful experiences in their graduate and professional career to meet their diverse goals. (2-0) Y

BMEN 6203 (BMEN 7203) Research Skills for Biomedical Engineers MS (2 semester credit hours) This course will introduce students to the research skills necessary for a successful graduate research career. Students will go through the process of planning and conducting a hands-on research project that can serve as the basis of a manuscript submission. Through this process students will learn research design terminology, steps in the research process, how to conduct systematic literature reviews, articulate clear research questions, testable hypotheses, and evaluate strengths and weaknesses of published articles. (2-1) Y

BMEN 6302 (EECS 6302 and MECH 6317 and SYSM 6302) Dynamics of Complex Networks and Systems (3 semester credit hours) Design and analysis of complex interconnected networks and systems. Basic concepts in graph theory; Eulerian and Hamiltonian graphs; traveling salesman problems; random graphs; power laws; small world networks; clustering; introduction to dynamical systems; stability; chaos and fractals. (3-0) Y

BMEN 6315 Advanced Biomaterials Technologies and Applications to Medical Devices (3 semester credit hours) This course will build upon graduate students' knowledge of biomaterials for biomedical engineering focused on development of materials for implantable medical devices (e.g., defibrillators, pacemakers, artificial heart valves, stents, catheters), medical implants (e.g., dental implants, artificial hips, knees, and elbows), implantable biosensors and drug delivery MEMS devices, and materials for a new generation of surgical instruments. Students will learn the fundamentals of novel bioengineering materials and technological developments for insertion of materials into commercial medical products, and they will have the opportunity to work in the laboratory to learn how to produce some of the bioengineering materials (e.g., biocompatible ultrananocrystlalline diamond coatings, biocompatible oxides films, and flexible polymers for implantable electronics and neural stimulation electrodes). (3-0) Y

BMEN 6321 Polymers for Biomedical Applications (3 semester credit hours) This course describes basic synthesis, characterization, and applications of synthetic and natural polymers. This course is designed for graduate students in all areas who are interested in biomedical applications of polymers including implantable devices, drug-delivery, and tissue engineering. Topics include: introduction to polymer chemistry and physics, biodegradable polymers, stimuli-responsive polymers, polymeric hydrogels, and current and future application of polymers in medicine. (3-0) Y

BMEN 6324 (EECS 6324 and MECH 6324 and SYSE 6326) Robot Control (3 semester credit hours) Dynamics of robots; methods of control; force control; robust and adaptive control; feedback linearization; Lyapunov design methods; passivity and network control; control of multiple and redundant robots; teleoperation. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307. (3-0) T

BMEN 6330 Introduction to Medical Device Development (3 semester credit hours) This course introduces students to the process of taking an engineering solution from a concept to the market place. This course will examine topics pertinent to engineering medical devices in regards to regulatory affairs, quality systems management, entrepreneurship, and clinical studies. (3-0) Y

BMEN 6331 Medical Device Regulations and Regulatory Strategy (3 semester credit hours) An in-depth review and analysis of biomedical engineering device approval pathways and processes that influence engineering design decisions along these pathways. This course will emphasize the essential skills and tools critical to the introduction of new medical devices, and necessary to the practice of biomedical engineering. Hands-on problem solving of real world biomedical engineering challenges, using critical thinking, data analysis, and interpretation skills. Students will be expected to work in teams to research, evaluate, and present scientifically and legally justifiable strategies for introduction of a biomedical engineering technology, through oral and written communication. Department consent required. (3-0) Y

BMEN 6332 Healthcare and Biotechnology Landscapes (3 semester credit hours) This course will take a systems biomedical engineering approach to examine the influence of the healthcare and medical device technology landscapes, laws and regulations on the innovation and commercialization processes for biomedical technologies. Students will build a strong understanding of healthcare and medical device business requirements through the introduction of a wide variety of topics relevant to commercializing technical medical innovations from multidisciplinary perspectives. Students will gain practical experience through the application of learned concepts in class projects and assignments related to biomedical engineering business strategy development, commercial execution, and operational sustainability. Department consent required. Prerequisite: BMEN 6331. (3-0) R

BMEN 6333 Quality Management Systems and Compliance (3 semester credit hours) A good Quality Management System (QMS) assures that products meet specifications efficiently and effectively to gain customer satisfaction, and as a result, gain profitability. This course will cover pre/post market QMS requirements and expectations of performance, best practices in QMS development, QMS evaluation for different audiences, the cost of poor quality, and the role this plays on how to meet customer satisfaction. This course will also engage students in quality system internal audits and regulatory external audit facilitation and negotiation, writing responses to allegations of non-conformance for the regulatory agencies, and the consequences that can be expected when regulatory enforcement ensues. Department consent required. (3-0) R

BMEN 6334 Ethical and Legal Clinical Trial Considerations (3 semester credit hours) This course will examine the historical events that influenced the existing federal regulations that guide clinical research as well as the current ethical codes and guidelines pertaining to the use of animals and humans as research subjects. Students will explore the framework and principles of Good Clinical Practice (GCP) as it relates to the roles and responsibilities of various stakeholders like the FDA, Investigator, Sponsor, IRB and the study subject. They will learn the main principles guiding the conduct of ethical research, the importance of transparency, balancing incentives for engineering innovation, adverse events management and determining and enforcing appropriate safety levels. This course will also cover the current reimbursement environment for clinical trials and its impact on clinical use of devices. Department consent required. Prerequisite: BMEN 6331. (3-0) R

BMEN 6335 Design for Human Use (3 semester credit hours) Medical device design must be controlled in a way that ensures its safety and fulfillment of its intended use. This course provides the engineering value of relevant regulation and guidance throughout the product life cycle and how that relates to product quality and ultimately, customer satisfaction. Students will learn how to evaluate and understand human needs as a basis for designing and engineering new technologies and the practical implementation of design controls, risk management, requirements engineering, transfer planning, configuration control, and records. Department consent required. Prerequisite: BMEN 6331. (3-0) R

BMEN 6336 Regulatory Strategy and Submission (3 semester credit hours) Through interactive lectures and facilitated group projects, students gain an understanding of the regulatory pathways and how to develop and use a regulatory strategy to overcome barriers to entry in the medical device market. This course provides hands-on experience working with the regulations, guidance documents, and tools needed to develop an effective regulatory submission, including how to integrate regulatory strategy with product development and design control activities. This course will include U.S. regulatory pathways and a comparison to OUS pathways and evaluate the benefits of using a STED submission for global registrations. Department consent required. Prerequisite: BMEN 6331. (3-0) R

BMEN 6337 Good Manufacturing Practices (3 semester credit hours) This course introduces students to the regulatory requirements and best practices for medical device good manufacturing practices. A wide range of engineering topics are taught that will expose students to the core concepts and deliverables in manufacturing engineering. Students will gain practical experience through the application of learned concepts in class projects and assignments related to engineering design and its manufacturing process development, planning, control, and improvement. Students will understand the influence of manufacturing throughout the regulated product lifecycle and learn to think critically and holistically when determining how to establish medical device manufacturing processes. Department consent required. Prerequisites: BMEN 6331 and BMEN 6333. (3-0) R

BMEN 6338 Six Sigma Yellow Belt for Biomedical Engineers (3 semester credit hours) The goal of this course is to prepare bioengineers in the techniques and methodologies related to Six Sigma. While Six Sigma generally aims to improve process performance and reduce variation via a systematic framework, the concepts and tools taught in this class extend into product design and are a valuable asset to quality assurance. Disclaimer: Although students will not receive the Six Sigma Yellow Belt certification from taking this course alone and this course is not associated with the American Society for Quality (ASQ), students will learn each Body of Knowledge needed to prepare for the certification examination using the recommended ASQ textbook. (3-0) R

BMEN 6342 Biomaterials and Medical Devices (3 semester credit hours) Covers advanced topics in the field of biomaterials which are used in the engineering design and testing of medical devices which are used to augment /replace soft and hard tissues. Overview of current challenges and successes with implantable devices, biomaterials properties, clinical requirements, clinical applications and cases, and in-vivo behavior of different classes of natural and synthetic materials. Advanced engineering analysis of biological response and biocompatibility, degradation and failure processes of implantable biomaterials/devices. Students will become familiar with several classes of biomaterials, their current clinical engineering applications, and state-of-the art research in the field. (3-0) Y

BMEN 6345 Self-Assembly of Biomaterials (3 semester credit hours) This course will introduce students to the emerging and evolving fields of self-assembly and nanoengineered biomaterials. Upon completion of the course students will understand the principles of self-assembly and self-organization of small molecules (e.g. thiols and surfactants), macromolecules (e.g. polymers, block co-polymers, proteins, DNA), and colloidal dispersions. Students will also learn the important role weak non-covalent forces (e.g. ionic bonds, hydrogen bonding, hydrophobic interactions) play in determining the structure of self-assembled systems. Finally students will learn how scientists and engineers are designing and exploiting the principles of self-assembly to produce functional biomaterials and the techniques to characterize these biomaterials from the nano to macro level. Topics to be covered include the following: Introduction to Self-Assembly; Intermolecular and Colloidal forces; Self-assembly in solutions micelles, bilayers, liquid crystals, emulsions; Colloidal Self-Assembly; Self-Assembly at Interfaces; Biomimetic Self-Assembly; Nanoparticles; and Nanostructured Films. Prerequisites: BIOL 2311 and CHEM 1312 and MATH 2417 and PHYS 2325 and instructor consent required. (3-0) Y

BMEN 6351 Biomedical Microdevices (3 semester credit hours) Introduction to concepts of medical microdevices; design methodology and its applications for diagnostics and therapeutics. (3-0) Y

BMEN 6355 (MSEN 6355) Nanotechnology and Sensors (3 semester credit hours) Introduction to the concept of nanotechnology, in context toward designing sensors/diagnostic devices. Identifying the impact of nanotechnology in designing "state-of-the art" sensors for healthcare applications. Topics include: nanotechnology and nanomaterials, principles of sensing and transduction and heterogeneous integration toward sensor design. (3-0) Y

BMEN 6365 Biomedical Image Processing (3 semester credit hours) This course covers basic digital image processing techniques used for the analysis of images. Topics include spatial and frequency domain filtering, image restoration, morphological operators (e.g., erosion and dilation) and their uses (e.g., boundary extraction, extraction of connected components), image segmentation and pattern recognition. A percentage of the course grade is based on projects, which require students to program image processing techniques and apply them to images. (3-0) Y

BMEN 6366 Image-Guided Drug Delivery (3 semester credit hours) This course will cover a variety of imaging modalities (MRI, Ultrasound, Optical Imaging) and how they are applicable to delivery of pharmaceutical drugs in vivo. This course will concentrate on current drug delivery strategies, barriers to delivery of specific molecules, and how image-guided approaches can be used to overcome these obstacles. While multiple topics in drug delivery will be discussed, a special emphasis will be placed on delivery of systemically administered compounds. Students will be expected to review and discuss current literature in image-guided drug delivery and design strategies for improving efficacy of therapeutic compounds using any of the imaging modalities discussed in class. This class will NOT focus on basics of imaging techniques or image processing. (3-0) Y

BMEN 6367 Artificial Intelligence in Biomedical Engineering (3 semester credit hours) This course covers the basic principles of artificial intelligence (AI) and its biological and medical applications. With recent progress in digitized data acquisition, machine learning, and computing infrastructure, AI is increasingly used in various fields of life. New breakthroughs and technologies are emerging from technology companies and research institutes at a rapid pace. Medicine is identified as one of the most promising application areas, and AI is changing the landscape of healthcare and biomedical research. This course will provide the basic principles of AI technologies, outline recent breakthroughs and their applications, and identify the challenges for further progress in medical AI systems. The course will also be featured by invited guest speakers who have real-world AI application experiences. All students should have extensive experience in computer programming and be familiar with Python programming. (3-0) Y

BMEN 6371 Bioelectric Systems (3 semester credit hours) Introduction to the theoretical and applied aspects of bioelectrical phenomena spanning cells to tissue. Beginning with a quantitative understanding of the basis of electrical excitability, the course covers bioelectrical signal propagation, the physical basis of extracellular potentials and stimulation, biopotential amplifier design and use, and clinically relevant biosignal acquisition and analyses. Department consent required. (3-0) Y

BMEN 6372 (MECH 6314 and SYSM 6306) Engineering Systems: Modeling and Simulation (3 semester credit hours) This course will present principles of computational modeling and simulation of systems. General topics covered include: parametric and non-parametric modeling; system simulation; parameter estimation, linear regression and least squares; model structure and model validation through simulation; and, numerical issues in systems theory. Techniques covered include methods from numerical linear algebra, nonlinear programming and Monte Carlo simulation, with applications to general engineering systems. Modeling and simulation software is utilized (MATLAB/SIMULINK). (3-0) Y

BMEN 6373 (EEBM 6373) Physiology and Immunology for Engineers (3 semester credit hours) This course provides an introduction to human physiology for engineers. Topics include antibodies, antigen-antibody interactions, HLA 1 & 2, complement, T and B cells, immunoregulation, tumor Immunobiology, basic and applied neuroscience, sensory systems, and neural interfaces. (3-0) Y

BMEN 6374 (EEBM 6374) Genes, Proteins and Cell Biology for Engineers (3 semester credit hours)

This course provides an introduction to principles of modern molecular and cellular biology for engineers and other non-life scientists. Topics include genes, protein structure and function, organization of cells and cellular trafficking. (3-0) Y

BMEN 6375 Techniques in Cell and Molecular Biology (3 semester credit hours) Introduction to cell and molecular laboratory techniques including DNA recombinant technology, protein biochemistry, structural biology, and molecular biology. Intended for engineers and other non-life-scientists. Prerequisite: BMEN 6374 or instructor consent required. (3-0) Y

BMEN 6377 Introduction to Protein Engineering (3 semester credit hours) Development of proteins with practical utility will be discussed, using examples and case studies taken from the current literature. Prerequisite: BMEN 6374 or instructor consent required. (3-0) Y

BMEN 6378 Mechanobiology for Engineers (3 semester credit hours) This course will introduce principles by which mechanical forces regulate biological processes in cells and tissues in healthy and diseased states. In order to understand mechanobiology from an engineering perspective, this course will review aspects of solid and fluid mechanics, cell biology, intracellular polymer mechanics, cellular mechanics and mechanotransduction, disease mechanisms, biological modeling and research methodology. In addition, the impact of mechanobiology in bone, arteries and various cell types will be discussed. (3-0) T

BMEN 6379 Mechanics of Soft Tissues (3 semester credit hours) This course covers several fundamental theories of solid mechanics that are needed to solve problems in biomechanics and biomaterials. The theories of nonlinear elasticity and viscoelasticity are applied to a large range of biomaterials and biological tissues, including bone, articular cartilage, blood vessels, the heart, and skeletal muscle. Other topics include muscle activation and the biomechanics of development, growth, and remodeling. Prerequisite BMEN 3399 or Graduate standing. (3-0) Y

BMEN 6380 (EEBM 6380) Introduction to Cellular Microscopy (3 semester credit hours) Image formation, diffraction, labeling techniques, fluorescence and image processing techniques will be introduced. (3-0) R

BMEN 6381 (EEBM 6381) Advanced Concepts in Microscopy (3 semester credit hours) Continuation of BMEN 6380, with emphasis on advanced approaches such as vectorial diffraction, stochastic aspects of image formation and analysis. Prerequisite: BMEN 6380 or EEBM 6380 or instructor consent required. (3-0) R

BMEN 6382 Systems Biology (3 semester credit hours) An interdisciplinary approach to biology. It explores experimental, theoretical, and computational approaches from mathematics, physics, and engineering for the understanding and analysis of biological problems. (3-0) Y

BMEN 6385 Biomedical Signals and Systems (3 semester credit hours) Time and Frequency domain analysis; continuous-time and discrete-time signals, linear-time invariant (LTI) systems and their properties. Frequency analysis of: LTI systems, continuous-time signals (Fourier series and Fourier transform) and discrete time signals [discrete Fourier series and discrete-time Fourier transform (DTFT)]. Sampling and signal reconstruction. Discrete Fourier transform (DFT) and fast Fourier transform (FFT). Filter design. MATLAB-based tutorials. Prerequisites: ENGR 2300 and EE 4310. (3-0) R

BMEN 6386 Biological Processes: Modeling and Simulation (3 semester credit hours) Introduces fundamental principles to develop and simulate mathematical and computer models of biological systems. Topics include modeling principles [continuous (differential equation models), discrete (Boolean network and Markov model), probabilistic (Bayesian network) and stochastic models] and model optimization. Methods to simulate mathematical biological models using computer programming (software: MATLAB) will be introduced. Prerequisite: MATH 2419 or equivalent. (3-1) R

BMEN 6387 (BIOL 5376) Applied Bioinformatics (3 semester credit hours) Genomic information content; data searches and multiple sequence alignment; mutations and distance-based phylogenetic analysis; genomics and gene recognition; polymorphisms and forensic applications; nucleic-acid and protein array analysis; structure prediction of biological macromolecules. Prerequisites: At least one semester of undergraduate statistics and probability, and two semesters of undergraduate calculus or instructor consent required. (3-0) T

BMEN 6388 (EECS 6336 and MECH 6313 and SYSE 6324) Nonlinear Systems (3 semester credit hours) Equilibria, phase portraits, linearization of nonlinear systems; periodic solutions; Poincare-Bendixson theorem; fundamental existence and uniqueness theorem for ODEs; Lyapunov stability theory; Invariance principle and LaSalle's theorem; converse theorems; singular perturbations; center manifold theorem; differential geometric tools, feedback linearization, input-output linearization, output injection, output tracking, passivity-based control; backstepping. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307 or equivalent. (3-0) T

BMEN 6389 (BIOL 6385 and MATH 6343) Computational Biology (3 semester credit hours) Machine learning and probabilistic graphical models have become essential tools for analyzing and understanding complex systems biology data in biomedical research. This course introduces fundamental principles and methods behind the most important high throughput data analysis tools. Applications will cover molecular evolutionary models, DNA/protein motif discovery, gene prediction, high-throughput sequencing and microarray data analysis, computational modeling gene expression regulation, and biological pathway and network analysis. Prerequisite: Some background in elementary statistics/probability or introductory bioinformatics, or instructor consent required. (3-0) Y

BMEN 6391 (BIOL 6373) Proteomics (3 semester credit hours) Protein identification, sequencing, and analysis of post-translational modifications by liquid chromatography/tandem mass spectrometry; determination of protein three dimensional structure by x-ray crystallography; its use in drug design; understanding protein interactions and function using protein chip microarrays. Prerequisites: one semester of undergraduate biochemistry and one semester of graduate biochemistry or instructor consent required. (3-0) T

BMEN 6392 Bioinstrumentation and Systems (3 semester credit hours) Introduction to bioinstrumentation, biomedical signal acquisition, isolation, amplification, and conditioning, biopotential electrodes and amplifiers for ECG, EEG, ENG and EMG. Vascular system dynamics.

Transmission and propagation of EM and RF signals around tissue. Biomedical applications. Prerequisite: BMEN 6385. (3-0) R

BMEN 6393 Neural Engineering Methods and Applications (3 semester credit hours) This course will cover Neural Engineering methods used for neural ensamble recording and neural stimulation. Electrodes and devices used in Brain Machine Interfacing (BMI), deep brain stimulation (DBS), spinal cord stimulation (SCS), transcranial direct current stimulation (TDCS), and Peripheral Nerve Interfacing will be covered. Advanced techniques including modulation by optogenomics and the development of new voltage fluorescent probes will be explained. The use of neural prosthesis for the restoration of sensory and motor function will be reviewed. This course will help students to understand a wide range of methodology currently use to interrogate and modulate the nervous system. Recommended prerequisites: (BMEN 3330 or equivalent) and (BMEN 3350 or equivalent). (3-0) Y

BMEN 6394 Medical Imaging Techniques and Image Processing (3 semester credit hours) In this course, the fundamental physical principals of modern medical imaging techniques will be covered, including x-ray, ultrasound, MRI, optical, nuclear, multi-modality imaging, and contrast agents. Students will also learn many common image processing methods, such as image reconstruction, filtering, segmentation, registration, and fitting. Recommended prerequisite: BMEN 3402 or equivalent. (3-0) R

BMEN 6395 Advanced Topics in Neuroscience for Engineers (3 semester credit hours) The purpose of this course is to explore principles of neural systems. An emphasis will be placed on the coding of neural information, neural plasticity in response to learning and injury, and considerations for engineering strategies to interface with the neurons system. Topics will include network and synaptic plasticity, timing, reward prediction, and coding of motor information. The course format will be a review of classical and emerging studies. Background knowledge of basic neuroscience is strongly encouraged. (3-0) R

BMEN 6396 CRISPR and Genome Editing (3 semester credit hours) The field of genome editing is experiencing a renaissance driven primarily by the repurposing of an immune response system utilized by bacteria and archaea. This system is characterized by the presence of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) stored in host genomes as memories of phage bacteria interactions. The use of the CRISPR-Cas9 system in higher organisms (including mammalian cells and animal models) has spurred myriads of applications critically relevant to agriculture, biomanufacturing, and human health. This course will introduce the general principles of CRISPR biology, provide training in the use of CRISPR for genome editing, highlight the latest research results, and discuss key scientific and technological challenges. (3-0) Y

BMEN 6V40 Individual Instruction in Biomedical Engineering (1-6 semester credit hours) Independent study under a faculty member's direction. May be repeated for credit as topics vary (6 semester credit hours maximum). Department consent required. ([1-6]-0) R

BMEN 6V70 Research in Biomedical Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit (6 semester credit hours maximum). Instructor consent required. ([1-6]-0) R

BMEN 6V87 Special Topics in Biomedical Engineering (1-9 semester credit hours) May be repeated for credit. Department consent required. ([1-9]-0) S

BMEN 6V98 Thesis (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

BMEN 7088 Departmental Seminar in Biomedical Engineering (0 semester credit hours) This course presents biomedical engineering students with a spectrum of topics presented by invited speakers. Students broaden their knowledge beyond their specific research areas and observe seminar presentations by recognized experts in different fields. Pass/Fail only. Must be repeated each semester for students in the doctoral program. May be repeated. (0-0) S

BMEN 7188 Advanced Seminars in Biomedical Engineering (1 semester credit hour) Doctoral students will learn to give effective short-formatted presentations about their research interests and findings, develop critical and relevant questions during a scientific talk, and use feedback to improve their presentation skills. Students will learn these skills through watching scientific presentations from their peers and by presenting aspects of their own research to their peers. May be repeated for credit (2 semester credit hours maximum). Department consent required. (1-0) R

BMEN 7189 Advanced Seminars in Biomedical Engineering II (1 semester credit hour) Doctoral students will continue learn to give effective short-formatted presentations about their research interests and findings, develop critical and relevant questions during a scientific talk, and use feedback to improve their presentation skills. Students will learn these skills through watching scientific presentations from their peers and by presenting aspects of their own research to their peers. Department consent required. Prerequisite: BMEN 7188. (1-0) Y

BMEN 7201 (BMEN 6201) Career Development Skills for Biomedical Engineers PhD (2 semester credit hours) Biomedical Engineering as a field requires a wide range of skills not traditionally taught in the classroom or lab, including self-presentation, collaboration, and science communication. This course bridges this knowledge gap through interactive training and assignments, and helps students to develop a career plan to help guide them to the most useful experiences in their graduate and professional career to meet their diverse goals. Required presentations help to prepare PhD students for dissertation defenses and job talks. (2-0) Y

BMEN 7203 (BMEN 6203) Research Skills for Biomedical Engineers PhD (2 semester credit hours) This course will introduce students to the research skills necessary for a successful graduate research career. Students will go through the process of planning and conducting a hands-on research project that can serve as the basis of a manuscript submission. Through this process students will learn research design terminology, steps in the research process, how to conduct systematic literature reviews, articulate clear research questions, testable hypotheses, and evaluate strengths and weaknesses of published articles. (2-1) Y

BMEN 7340 Experimental Methods and Statistical Analysis (3 semester credit hours) In this course, students will learn (1) experimental study designs and observational study designs, (2) how to perform exploratory data analysis, univariance and bivariance analysis, assess data quality, the treatment of outliers, (3) how to choose and perform inference statistical analyses, after verifying the assumptions behind statistical analyses. Students will understand p values are not the only way to determine the significance in inferential statistics, and p values are not sufficient in some cases, (4) how to perform nonparameric bootstrap statistic analysis for small sample size, and (5) how to consider and compare alternative models, how to interpret the results with evidence-based approach. Department consent required. (3-0) S

BMEN 7341 Biostatistics (3 semester credit hours) Biostatistics for Biomedical Engineers provides instruction on selected, important topics in biostatistical concepts and reasoning. Specific topics include tools for describing central tendency and variability in data; determining and justifying sample size; formulating hypotheses; selecting appropriate statistical analysis techniques; methods for performing inference on population means and proportions via sample data; statistical hypothesis testing and its application to group comparisons; general principles of study design; review of methods for comparison of discrete and continuous data; correlation and regression. This course emphasizes the practical application of skills for statistical interpretation of research data. Prerequisites: PhD standing and department consent required. (3-0) Y

BMEN 7342 Design of Experiments (3 semester credit hours) This graduate level course will walk students through the basics of experimental design in biomedical engineering with a focus on the practical application of skills and concepts to student research. Specific topics include understanding types of data; independent vs. dependent variables; design and selection of experimental controls; reagent standards and equipment calibration; forming robust, testable hypotheses; the danger of assumption; calculating sample size and power; forming evidence based conclusions; confounds and error; IRB documentation; selection of well-suited laboratory animals; informed consent; ethics in research; results forecasting; graphical representation of results; articulation of the research findings, and the implications of the findings in view of the strengths and weaknesses. Software packages including Excel and GraphPad will be demonstrated. Journal articles, including infamous retractions, will be reviewed and assessed for flaws in experimental design. Student-designed experiments relating to their work will be presented and reviewed. Prerequisites: PhD standing and department consent required. (3-0) Y

BMEN 7387 Independent Scientific Research in Biomedical Engineering (3 semester credit hours) This course deals with both the theoretical and practical aspects of designing dissertation research and successfully defending the design in the dissertation proposal and /or dissertation examination. The research design component will be targeted to a specific independent project with the intent that the project will develop into the student's dissertation. The primary focus is on developing a sound research design with appropriate controls and statistical power analyses. May be repeated (9 semester credit hours maximum). (3-0) S

BMEN 7V87 Advanced Topics in Biomedical Engineering (1-9 semester credit hours) Independent scientific research in Bioengineering. May be repeated for credit as topics vary. Department consent required. ([1-9]-0) S

BMEN 7V95 Special Topics in Biomedical Engineering (1-9 semester credit hours) Advanced specialized topics in Biomedical Engineering. Subject matter will vary from semester to semester. May be repeated for credit as topics vary (9 semester credit hours maximum). Prerequisites: PhD

Standing and department consent required. ([1-9]-0) R

BMEN 8188 Advanced Seminars in Biomedical Engineering III (1 semester credit hour) Doctoral students will continue learn to give long-formatted presentations about their research as a part of preparing for their dissertation defense, conference talks, and job talks. Students will learn these skills through watching scientific presentations from their peers and by presenting aspects of their own dissertation work to their peers. Department consent required. (1-0) Y

BMEN 8V40 Advanced Instruction in Biomedical Engineering (1-9 semester credit hours) Advanced research in biomedical engineering. Pass/Fail only. May be repeated for credit. Department consent required. ([1-9]-0) R

BMEN 8V70 Advanced Research In Biomedical Engineering (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) R

BMEN 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

Computer Engineering

CE 5325 (EEDG 5325) Hardware Modeling Using HDL (3 semester credit hours) This course introduces students to hardware description languages (HDL) beginning with simple examples and describing tools and methodologies. It covers the language, dwelling on fundamental simulation concepts. Students are also exposed to the subset of HDL that may be used for synthesis of custom logic. HDL simulation and synthesis labs and projects are performed using commercial and/or academic VLSI CAD tools. Prerequisite: EE 3320 or equivalent. (3-0) T

CE 6301 (EEDG 6301) Advanced Digital Logic (3 semester credit hours) Modern design techniques for digital logic. Logic synthesis and design methodology. Link between front-end and back-end design flows. Field programmable gate arrays and reconfigurable digital systems. Introduction to testing, simulation, fault diagnosis and design for testability. Prerequisites: EE 3320 or equivalent and background in VHDL/Verilog. (3-0) T

CE 6302 (EEDG 6302) Microprocessor and Embedded Systems (3 semester credit hours) Design of microprocessor based systems including I/O and interface devices. Programming of micro-controllers and embedded systems. Microprocessor architectures. Use of emulators and other sophisticated test equipment. Extensive laboratory work. Lab fee of $30 required. Prerequisites: EE 4304 or equivalent and background in VHDL/Verilog. (2-3) Y

CE 6303 (EEDG 6303) Testing and Testable Design (3 semester credit hours) Techniques for detection of failures in digital circuits and systems. Fault modeling and detection. Functional testing and algorithms for automatic test pattern generation (ATPG). Design of easily testable digital systems. Techniques for introducing built-in self test (BIST) capability. Test of various digital modules, such as PLA's, memory circuits, datapath, etc. Prerequisites: EE 3320 or equivalent and background in VHDL/Verilog. (3-0) Y

CE 6304 (CS 6304 and EEDG 6304) Computer Architecture (3 semester credit hours) Trends in processor, memory, I/O and system design. Techniques for quantitative analysis and evaluation of computer systems to understand and compare alternative design choices in system design. Components in high performance processors and computers: pipelining, instruction level parallelism, memory hierarchies, and input/output. Students will undertake a major computing system analysis and design project. Must have an understanding of C/C++. Prerequisite: CS 2340 or EE 4304. (3-0) Y

CE 6306 (EEDG 6306) Application Specific Integrated Circuits Design (3 semester credit hours) This course discusses the design of application specific integrated circuits (ASIC). Specific topics include: VLSI system design specification, ASIC circuit structures, synthesis, and implementation of an ASIC digital signal processing (DSP) chip. Prerequisite: EE 3320. (3-0) Y

CE 6308 (CS 6396 and EEDG 6308) Real-Time Systems (3 semester credit hours) Introduction to real-time applications and concepts. Real-time operating systems and resource management. Specification and design methods for real-time systems. System performance analysis and optimization techniques. Project to specify, analyze, design, implement and test small real-time system. Prerequisite: CS 5348. (3-0) R

CE 6309 (EEDG 6309) Applications of Machine Learning in Semiconductor IC Manufacturing and Test (3 semester credit hours) Fundamentals of machine learning, including regression, classification, feature extraction, feature selection, synthetic training set enhancement, boosting and curse of dimensionality; test cost reduction via test compaction, alternate test, adaptive test and effectiveness metrics; wafer-level spatial and spatio-temporal correlation modeling, process variation decomposition, process monitoring, outlier detection yield prediction; post-manufacturing tuning and post-deployment calibration of analog/RF ICs; security and trust assessment, including hardware Trojan detection, counterfeit IC identification, and fab-of-origin attestation. Experience with Machine Learning methods and software desirable but not required. Prerequisite: CE 6301 or EEDG 6301 or CE 6303 or EEDG 6303 or CE 6325 or EECT 6325 or EECT 6326. (3-0) Y

CE 6310 (EEDG 6310) Hardware Security (3 semester credit hours) Theory of cryptography for security, an overview of both classical and emerging attack methods and methodologies and possible defenses against them with respect to silicon-on-chip security, side-channel attacks, hardware trojans, physically unclonable functions, IC counterfeit protection, and hardware-based malware detection. (3-0) Y

CE 6312 (EEDG 6312) Computing with Emerging Technologies (3 semester credit hours) Integration of emerging technologies in novel computing systems. Relevant devices include various spintronic devices, carbon nanotubes, graphene, memristors, and multi-gate FETs. Relevant computational functions include Boolean logic, as well as neuromorphic, threshold, stateful, quantum, and stochastic computing systems. (3-0) Y

CE 6325 (EECT 6325) VLSI Design (3 semester credit hours) Introduction to MOS transistors. Analysis of the CMOS inverter. Combinational and sequential design techniques in VLSI; issues in static, transmission gate and dynamic logic design. Design and layout of complex gates, latches and flip-flops, arithmetic circuits, memory structures. Low power digital design. The method of logical effort. CMOS technology. Use of CAD tools to design, layout, check, extract and simulate a small project. Prerequisites: EE 3301 and EE 3320 or equivalent. (3-0) S

CE 6330 (EEDG 6330) Applied Cryptography (3 semester credit hours) This course presents a wide range of cryptographic principles and their implementation in software/hardware. This includes: security properties; block and stream ciphers, their basic implementations, and various ways to attack them including side-channel attacks; public-key schemes using number/group-theoretic techniques; advanced protocols; and resilient implementation techniques. Basic familiarity with algorithms, probability, and algebra needed. Credit cannot be received for both CS 6377 and (CE 6330 or EEDG 6330). Prerequisite: ENCS majors only. (3-0) Y

CE 6331 (EEDG 6331) High-Level Synthesis: Design and Verification (3 semester credit hours) Facilitate the design of dedicated hardware using higher levels of abstraction (ANSI-C, C++ or SystemC) instead of hardware description languages like Verilog or VHDL. Theory of HLS process is comprehensively studied including: technology independent optimizations, resource allocation, scheduling, and binding stages. Students will design different types of hardware accelerators using HLS and learn how to design and verify complete hardware systems using only C. Course projects may include, but are not limited to: Building an automated HLS design space explorer, design of neural networks and building complete systems in C. Commercially available EDA tools will be used during the course. Prerequisite: EE3320 or equivalent, C/C++. (3-0) Y

CE 6350 Computer Engineering Practicum (3 semester credit hours) Student gains experience and improves design and development skills for large scale software and/or hardware systems. Student must identify and submit a real-world project with specific goals and learning objectives at the beginning of the semester. At the semester end, student must prepare an oral or poster presentation or a written paper reflecting on the work experience. Department consent required. (3-0) Y

CE 6351 Computer Engineering Internship (3 semester credit hours) Student gains experience and improves design and development skills for large scale software and/or hardware systems through appropriate developmental work assignments in a real business environment. Student must identify and submit a real-world project with specific goals and learning objectives at the beginning of the semester. At the semester end, student must prepare an oral or poster presentation or a written paper reflecting on the work experience. Department consent required. (3-0) R

CE 6368 (EESC 6368) Multimodal Deep Learning (3 semester credit hours) Theory and applications in the field of multimodal deep learning. Robustness and performance of systems by considering cross-modal integration. Deep learning methods used for representation, translation, alignment, fusion, and co-learning of multimodal content. Multimodal embeddings and their applications. Use of deep learning solutions such as convolutional neural network (CNN), Long short-term memory (LSTM), and attention models to process multimodal data. Recommended Corequisite: EESC 6349. Prerequisite: ENGR 3341 or equivalent. (3-0) T

CE 6370 (EEDG 6370) Design and Analysis of Reconfigurable Systems (3 semester credit hours) Introduction to reconfigurable computing, programmable logic: FPGAS, CPLDs, CAD issues with

FPGA based design, reconfigurable systems: emulation, custom computing, and embedded application based computing, static and dynamic hardware, evolutionary design, software environments for reconfigurable systems. Prerequisite: EE 3320 or equivalent. (3-0) R

CE 6375 (EEDG 6375) Design Automation of VLSI Systems (3 semester credit hours) This course deals with various topics related to the development of CAD tools for VLSI systems design. Algorithms, data structures, heuristics and design methodologies behind CAD tools. Design and analysis of algorithms for layout, circuit partitioning, placement, routing, chip floor planning, and design rule checking (DRC). Introduction to CAD algorithms for RTL and behavior level synthesis, module generators, and silicon compilation. (3-0) Y

CE 6V98 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

CE 7325 (EECT 7325) Advanced VLSI Design (3 semester credit hours) Advanced topics in VLSI design covering topics beyond the first course (EECT 6325). Topics include: use of high-level design, synthesis, and simulation tools, clock distribution and routing problems, (a)synchronous circuits, low-power design techniques, study of various VLSI-based computations, systolic arrays, etc. Discussions on current research topics in VLSI design. Prerequisite: EECT 6325 or equivalent. (3-0) R

CE 7V80 Special Topics in Computer Engineering (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum.) Prerequisite: ENCS majors only and instructor consent required. ([1-6]-0) S

CE 8V40 Individual Instruction in Computer Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-6]-0) R

CE 8V70 Research in Computer Engineering (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) R

CE 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

Computer Science

CS 5302 Topics in Computer Science (3 semester credit hours) May be repeated for credit as topics vary (6 semester credit hours maximum). Prerequisite: CS 5343. (3-0) Y

CS 5303 Computer Science I (3 semester credit hours) Computer science problem solving. The structure and nature of algorithms and their corresponding computer program implementation. Programming in a high level block-structured language (e.g., PASCAL, Ada, C++, or JAVA). Elementary data structures: arrays, records, linked lists, trees, stacks and queues. Prerequisite: ENCS majors only. (3-0) R

CS 5330 Computer Science II (3 semester credit hours) Basic concepts of computer organization: Numbering systems, two's complement notation, multi-level machine concepts, machine language, assembly programming and optimization, subroutine calls, addressing modes, code generation process, CPU datapath, pipelining, RISC, CISC, and performance calculation. Prerequisite or Corequisite: CS 5303. (3-0) R

CS 5333 Discrete Structures (3 semester credit hours) Mathematical foundations of computer science. Logic, sets, relations, graphs and algebraic structures. Combinatorics and metrics for performance evaluation of algorithms. Prerequisite: ENCS majors only. (3-0) S

CS 5343 Algorithm Analysis and Data Structures (3 semester credit hours) Formal specifications and representation of lists, arrays, trees, graphs, multilinked structures, strings, and recursive pattern structures. Analysis of associated algorithms. Sorting and searching, file structures. Relational data models. Prerequisite: CS 5303. Prerequisite or Corequisite: CS 5333. (3-0) S

CS 5348 Operating Systems Concepts (3 semester credit hours) Processes and threads. Concurrency issues including semaphores, monitors and deadlocks. Simple memory management. Virtual memory management. CPU scheduling algorithms. I/O management. File management. Introduction to distributed systems. Must have a working knowledge of C and Unix. Prerequisite: CS 5330. Prerequisite or Corequisite: CS 5343. (3-0) S

CS 5349 Automata Theory (3 semester credit hours) Deterministic and nondeterministic finite automata; regular expressions, regular sets, context-free grammars, pushdown automata, context free languages. Selected topics from Turing Machines and undecidability. Prerequisite: CS 5333. (3-0) S

CS 5375 Principles of UNIX (3 semester credit hours) Design and history of the UNIX operating system. Detailed study of process and file system data structures. Shell programming in UNIX. Use of process-forking functionality of UNIX to simplify complex problems. Interprocess communication and coordination. Device drivers and streams as interfaces to hardware features. TCP/IP and other UNIX inter-machine communication facilities. Recommended prerequisite: CS 3335. Prerequisite: CS 5343. (3-0) S

CS 5390 Computer Networks (3 semester credit hours) The design and analysis of protocols for computer networking. Topics include: network protocol design and composition via layering, contention resolution in multi-access networks, routing metrics and optimal path searching, traffic management, global network protocols; dealing with heterogeneity and scalability. Prerequisite: CS 5343. (3-0) S

CS 5V81 Special Topics in Computer Science (1-9 semester credit hours) May be repeated as topics vary (9 semester credit hours maximum). Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

CS 6301 Special Topics in Computer Science (3 semester credit hours) May be repeated for credit as topics vary. Prerequisite: CS 5343. (3-0) S

CS 6302 Special Topics in Computer Science (3 semester credit hours) Special Topics in Computer Science for Non-CS/SE Majors. Prerequisite: CS 5303. (3-0) Y

CS 6303 Cyber Security Essentials for Practitioners (3 semester credit hours) The Cybersecurity Essentials course develops a foundational understanding of cybersecurity as a business risk. This class will help identify threats to an organization and how they relate to cyber security. An in-depth understanding of the different types of cyberattacks, the business systems that are most at risk, and the importance of an organization-wide approach to cybersecurity. This course will also cover the crucial role of leadership in managing cyber risk throughout the entire organization. May not be used to satisfy the degree requirements of the MS CS or the MS SE degree plans. (3-0) Y

CS 6304 (CE 6304 and EEDG 6304) Computer Architecture (3 semester credit hours) Trends in processor, memory, I/O and system design. Techniques for quantitative analysis and evaluation of computer systems to understand and compare alternative design choices in system design. Components in high performance processors and computers: pipelining, instruction level parallelism, memory hierarchies, and input/output. Students will undertake a major computing system analysis and design project. Must have an understanding of C/C++. Prerequisite: CS 2340 or EE 4304. (3-0) Y

CS 6305 Data Security and Privacy for Practitioners (3 semester credit hours) The course will teach principles, tools, and trends for data and application security and privacy. Topics to be covered include: confidentiality, privacy and trust management. Additionally, best practices and policies to promote secure databases, distributed systems, and applications such as social media systems, the cloud, and IoT systems will be covered. In addition, the privacy implications of data analytics and potential solutions will be discussed. Students will assess one system or application to identify potential vulnerabilities and identify possible remediations. The topics include an overview of common and emerging vectors of attack and the best practices for deterring them. May not be used to satisfy degree requirements for the MS CS or the MS SE degree plans. (3-0) Y

CS 6306 Cyber Security Analytics & Malware Analysis for Practitioners (3 semester credit hours) A supervisory view of security vulnerabilities in information systems, applications and safe computing. Additionally, best practices to promote security standards and applications, management and analysis of security. Applications of data science techniques, preparation for adversarial attacks. May not be used to satisfy degree requirements for the MS CS or the MS SE degree plans. (3-0) Y

CS 6307 Introduction to Big Data Management and Analytics for non CS-Majors (3 semester credit hours) Database fundamentals including Query Processing, Parallel/Distributed Data Processing, NoSQL systems (e.g., Key-value stores, Column-oriented data stores, MapReduce), Graph Processing, and Recommendation Systems using Big Data technologies. This course cannot be used to satisfy the requirements for the MS CS or the MS SE degree plans. Prerequisites: (CS 5303 or equivalent) and (CS 5343 or equivalent). (3-0) Y

CS 6308 Cyber Physical Systems and Critical Infrastructure Security for Practitioners (3 semester credit hours) The Stuxnet attack was a wake-up call to improve the security of our critical infrastructures, which include transportation networks, the power grid, and other cyber-physical systems, where computation, communications, and control are tightly integrated. This class covers the security of cyber-physical systems from a multi-disciplinary point of view, from computer science security research (network security and software security), to public policy (e.g., the Executive Order 13636), risk-assessment, business drivers, and control-theoretic methods to reduce the cyber-risk to cyber-physical critical infrastructures. Students are required to participate in several cyber war games. May not be used to satisfy degree requirements for the MS CS or the MS SE degree plans. (3-0) Y

CS 6313 (STAT 6313) Statistical Methods for Data Science (3 semester credit hours) Statistical methods for data science. Statistical Methods are developed at an intermediate level. Sampling distributions. Point and interval estimation. Parametric and nonparametric hypothesis testing. Analysis of variance. Regression, model building and model diagnostics. Monte Carlo simulation and bootstrap. Introduction to a statistical software package. Prerequisite: CS 3341 or SE 3341 or STAT 3341 or equivalent. (3-0) S

CS 6314 Web Programming Languages (3 semester credit hours) Advanced understanding of web architecture, standards, protocols, tools, and technologies. Tools required for web programming including HTML, CSS, and JavaScript; XML and database technologies; server-side programming using PHP; Web security protocols and standards; techniques and algorithms related to web services, cloud computing, and semantic web. Prerequisite: CS 5343. (3-0) S

CS 6315 Semantic Web (3 semester credit hours) History and foundations of semantic web. URIs and namespaces; XML and XMLS Datatypes, RDF and RDF/XML, RDFS, and OWL (Lite, DL and Full); applications of semantic web; introduction to OWL 2 features and profiles; design patterns used in the creation of semantic web solutions. Prerequisite: CS 5343. (3-0) S

CS 6319 Computational Geometry (3 semester credit hours) This course will cover basic computational geometry topics, such as computing convex hulls, computing Voronoi diagrams and Delaunay triangulations, motion planning, and the main methods for developing geometric algorithms. We will also discuss various geometric data structures for point location and range searching and additional topics at the discretion of the instructor, such as geometric approximation and high dimensional data analysis. Prerequisite: CS 5343. (3-0) Y

CS 6320 Natural Language Processing (3 semester credit hours) This course covers state-of-the-art methods for natural language processing. After an introduction to the basics of syntax, semantic, and discourse analysis, the focus shifts to the integration of these modules into natural-language processing systems. In addition to natural language understanding, the course presents advanced material on lexical knowledge acquisition, natural language generation, machine translation, and parallel processing of natural language. Prerequisite: CS 5343. (3-0) Y

CS 6321 Discourse Processing (3 semester credit hours) Introduction to discourse processing from natural language texts. Automatic clustering of utterances into coherent units (segments) with hierarchical structures. State-of-the-art research in textual cohesion, coherence, and discourse understanding. Included topics are anaphoric reference and ellipsis, notion of textual context, and relationship between tense, aspect, and discourse states. Prerequisite: CS 6320. (3-0) T

CS 6322 Information Retrieval (3 semester credit hours) This course covers modern techniques for storing and retrieving unformatted textual data and providing answers to natural language queries. Current research topics and applications of information retrieval in data mining, data warehousing, text mining, digital libraries, hypertext, multimedia data, and query processing are also presented. Prerequisite: CS 5343. (3-0) Y

CS 6323 Computer Animation and Gaming (3 semester credit hours) Theoretical foundations and programming techniques involved in computer animation and game engines. Specific topics include 2D and 3D transformations, skeletons, forward and inverse kinematics, skinning, keyframing, particle systems, rigid bodies, cloth animation, collision detection, and animation for video games. Prerequisites: CS 5343 and a good working knowledge of C++ and graphical programming (either OpenGL, DirectX, or Java3D). (3-0) Y

CS 6324 Information Security (3 semester credit hours) A comprehensive study of security vulnerabilities in information systems and the basic techniques for developing secure applications and practicing safe computing. Topics include common attacking techniques such as buffer overflow, Trojan, virus, etc. UNIX, Windows and Java security. Conventional encryption. Hashing functions and data integrity. Public-key encryption (RSA, Elliptic-Curve). Digital signature. Watermarking for multimedia. Security standards and applications. Building secure software and systems. Management and analysis of security. Legal and ethical issues in computer security. Prerequisites: CS 5343 and CS 5348. (3-0) Y

CS 6326 Human Computer Interactions (3 semester credit hours) In-depth exploration of human-computer interactions (HCI). Models and principles of HCI. The user experience (UX) lifecycle and design guidelines for a wide variety of advanced interfaces, such as mobile devices and 3D sensors. UX evaluation of interface designs. Prerequisite: CS 5343. (3-0) Y

CS 6327 Video Analytics (3 semester credit hours) In-depth analysis of topics such as: video features for (human) activity and event detection; large-scale video event classification algorithms; objects-in-video counting approaches; multi-camera video handling; compressed video event detection and analyzing video in large-scale human traffic areas (such as shopping malls, airports, train-stations, etc.). Prerequisite: CS 5343. (3-0) Y

CS 6328 Modeling and Simulation (3 semester credit hours) Theory and practice of modeling, including models for concepts, knowledge, geometry, and dynamics. A variety of model types are covered along with their algebraic and diagrammatic representations. Creative media design and representation of models is stressed. Prerequisite: CS 5343 or instructor consent required. (3-0) R

CS 6331 Multimedia Systems (3 semester credit hours) Analyzing and understanding how different media data (such as text, audio, images, video, and 3D graphics) can be stored, queried, delivered, and consumed. These aspects will be discussed from the point of view of the operating system, databases, and networking. Prerequisite: CS 5343. (3-0) Y

CS 6332 Systems Security and Malicious Code Analysis (3 semester credit hours) Concepts, techniques, and tools to capture the structure, format, and representation of binary code, and transform them for higher level analysis. Use of static analysis including data-flow analysis, point-to analysis, and shape analysis to reason about the abstractions inside binary code. Use of dynamic binary instrumentation to trace the instruction level behavior of both benign and malicious programs. Use of virtual machines to observe the whole system level behavior including OS kernels. Prerequisites: CS 5343 and CS 5348 and knowledge of Assembly Code. (3-0) Y

CS 6334 Virtual Reality (3 semester credit hours) Theory and practice of virtual reality (VR). Provides in-depth overview of VR, including input devices, output devices, 3D navigation techniques, 3D selection and manipulation techniques, system control techniques, interaction fidelity, scenario fidelity, display fidelity, design guidelines, and evaluation methods. Prerequisite: CS 5343. (3-0) Y

CS 6340 Wireless Networks (3 semester credit hours) Fundamental techniques in design and operation of the 2G-5G wireless cellular networks and wireless LANs, including the control and the data planes. Introduction to future technologies, such as 6G and IoT. The course is a mix of qualitative and quantitative presentation. Prerequisites: CS 5390 and (CS 3341 or SE 3341 or STAT 3341) or equivalent. (3-0) Y

CS 6343 Cloud Computing (3 semester credit hours) Different layers of cloud computing, infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). Data centers. Resource management, power management, and health monitoring in IaaS cloud. Hadoop MapReduce for big data computing. PaaS examples such as GAE, Force.com. SaaS concepts and enabling technologies. Cloud storage theory and practical solutions such as GFS, Big Table, HDFS, HBase, Dynamo, Pnuts. Erasure coding and secret sharing based cloud storage. Virtualization and emulation. Server virtualization, storage virtualization, and network virtualization. Cloud security. Prerequisites: CS 5343 and CS 5348. (3-0) S

CS 6344 Data Representations (3 semester credit hours) Useful representations of data for efficient manipulation and visualization. These include, among others Dimensionality Reduction, Clustering, Euclidean Embedding, Graph Embedding, and Discriminant Functions. Techniques covered include principal component analysis (PCA), singular value decomposition (SVD), clustering, and various randomized techniques. Special emphasis is given to the performance of these techniques on big data. Prerequisite: CS 5343. (3-0) Y

CS 6346 Introduction to Multicore Programming (3 semester credit hours) Introduction to multi-core and GPU architecture concepts. Classic and modern algorithms for coordination and synchronization. Blocking and non-blocking synchronization. Correctness conditions and reasoning about concurrent algorithms. Data structures that exploit and extract performance from multiple cores. Concurrent memory reclamation techniques. GPU programming with CUDA. Prerequisites: CS 5343 and CS 5348. (3-0) Y

CS 6347 Statistical Methods in AI and Machine Learning (3 semester credit hours) Introduction to the probabilistic and statistical techniques used in modern computer systems. Probabilistic graphical models such as Bayesian and Markov networks. Probabilistic inference techniques including variable elimination, belief propagation and its generalizations, and sampling-based algorithms such as importance sampling and Markov Chain Monte Carlo sampling. Statistical learning techniques for learning the structure and parameters of graphical models. Sequential models such as Hidden Markov models and Dynamic Bayesian networks. Prerequisites: (CS 3341 or equivalent) and (CS 5343 or equivalent). (3-0) Y

CS 6348 Data and Applications Security (3 semester credit hours) The course will teach principles, technologies, tools and trends for data, and applications security and privacy. Topics to be covered include: confidentiality, privacy and trust management; advanced access control policy management; secure databases; secure distributed systems; encryption techniques for database security; blockchain based techniques for ensuring data integrity; data privacy; privacy-preserving data mining. Students will take one system or application and develop a secure version of that system or application for the programming project. Prerequisite: CS 5343. (3-0) Y

CS 6349 Network Security (3 semester credit hours) This course covers theoretical and practical aspects of network security. The topics include use of cryptography for building secure communication protocols and authentication systems; security handshake pitfalls, Kerberos and PKI, security of TCP/IP protocols including IPsec, BGP security, VPNs, IDSes, firewalls, and anonymous routing; security of TCP/IP applications; wireless LAN security; denial-of-service defense. Students are required to do a programming project building a distributed application with certain secure communication features and required to participate in several network security lab exercises and cyber war games. Prerequisites: CS 5390. (3-0) Y

CS 6350 Big Data Management and Analytics (3 semester credit hours) This course focuses on scalable data management and mining algorithms for analyzing very large amounts of data (i.e., Big Data). Included topics are: Mapreduce, NoSQL systems (e.g., key-value stores, column-oriented data stores, stream processing systems), association rule mining, large scale supervised and unsupervised learning, state of the art research in data streams, and applications including recommendation systems, web and big data security. Prerequisites: CS 6360 and Java programming. (3-0) S

CS 6352 Performance of Computer Systems and Networks (3 semester credit hours) Overview of case studies. Quick review of principles of probability theory. Queuing models and physical origin of random variables used in queuing models. Various important cases of the M/M/m/N queuing system. Little's law. The M/G/1 queuing system. Simulation of queuing systems. Product form solutions of open and closed queuing networks. Convolution algorithms and Mean Value Analysis for closed queuing networks. Discrete time queuing systems. Prerequisites: ENCS majors only and a first course on probability theory. (3-0) S

CS 6353 Compiler Construction (3 semester credit hours) Lexical analyzers, context-free grammars. Top-down and bottom-up parsing; shift reduce and LR parsing. Operator-precedence, recursive-descent, predictive, and LL parsing. LR(k), LL(k) and precedence grammars will be covered. Prerequisites: CS 5343 and CS 5349. (3-0) Y

CS 6356 (SE 6356 and SYSM 6308) Software Maintenance, Evolution, and Re-Engineering (3 semester credit hours) Principles and techniques of software maintenance. Impact of software development process on software justifiability, maintainability, evolvability, and planning of release cycles. Use of very high-level languages and dependencies for forward engineering and reverse engineering. Achievements, pitfalls, and trends in software reuse, reverse engineering, and re-engineering. Prerequisite: SE 5354. (3-0) Y

CS 6359 Object-Oriented Analysis and Design (3 semester credit hours) Analysis and practice of modern tools and concepts that can help produce software that is tolerant of change. Consideration of the primary tools of encapsulation and inheritance. Construction of software-ICs which show the parallel with hardware construction. Prerequisite: CS 5343. (3-0) S

CS 6360 Database Design (3 semester credit hours) Methods, principles, and concepts that are relevant to the practice of database software design. Database system architecture; conceptual database models; relational and object-oriented databases; database system implementation; query processing and optimization; transaction processing concepts, concurrency, and recovery; security. Prerequisite: CS 5343. (3-0) S

CS 6361 (SE 6361 and SYSM 6309) Advanced Requirements Engineering (3 semester credit hours) System and software requirements engineering. Identification, elicitation, modeling, analysis, specification, management, and evolution of functional and non-functional requirements. Strengths and weaknesses of different techniques, tools, and object-oriented methodologies. Interactions and trade-offs among hardware, software, and organization. System and sub-system integration with software and organization as components of complex, composite systems. Transition from requirements to design. Critical issues in requirements engineering. Prerequisite: SE 5354. (3-0) S

CS 6363 Design and Analysis of Computer Algorithms (3 semester credit hours) The study of efficient algorithms for various computational problems. Algorithm design techniques. Sorting, manipulation of data structures, graphs, matrix multiplication, and pattern matching. Complexity of algorithms, lower bounds, NP completeness. Prerequisites: CS 5333 and CS 5343. (3-0) S

CS 6364 Artificial Intelligence (3 semester credit hours) Design of machines that exhibit intelligence. Particular topics include: representation of knowledge, vision, natural language processing, search, logic and deduction, expert systems, planning, language comprehension, and machine learning. Prerequisite: CS 5343. (3-0) Y

CS 6366 Computer Graphics (3 semester credit hours) Device and logical coordinate systems. Geometric transformations in two and three dimensions. Algorithms for basic 2-D drawing primitives, such as Brensenham's algorithm for lines and circles, Bezier and B-Spline functions for curves, and line and polygon clipping algorithms. Perspectives in 3-D, and hidden-line and hidden-face elimination, such as Painter's and Z-Buffer algorithms. Fractals and the Mandelbrot set. Prerequisites: CS 5330 and CS 5343 and MATH 2418. (3-0) Y

CS 6367 (SE 6367 and SYSM 6310) Software Testing, Validation and Verification (3 semester credit hours) Fundamental concepts of software testing. Functional testing. GUI based testing tools. Control flow based test adequacy criteria. Data flow based test adequacy criteria. White box based testing tools. Mutation testing and testing tools. Relationship between test adequacy criteria. Finite state machine based testing. Static and dynamic program slicing for testing and debugging. Software reliability. Formal verification of program correctness. Prerequisite: SE 5354. (3-0) Y

CS 6368 Telecommunication Network Management (3 semester credit hours) In-depth study of network management issues and standards in telecommunication networks. OSI management protocols including CMIP, CMISE, SNMP, and MIB. ITU's TMN (Telecommunication Management

Network) standards, TMN functional architecture and information architecture. NMF (Network Management Forum) and service management, service modeling and network management API. Issues of telecommunication network management in distributed processing environment. Prerequisite: CS 5390. (3-0) Y

CS 6371 Advanced Programming Languages (3 semester credit hours) Functional programming, Lambda calculus, logic programming, abstract syntax, denotational semantics of imperative languages, fixpoints semantics, verification of programs, partial evaluation, interpretation and automatic compilation, axiomatic semantics, applications of semantics to software engineering. Prerequisites: CS 5343 and CS 5349. (3-0) S

CS 6373 Intelligent Systems (3 semester credit hours) Logical formalizations of knowledge for the purpose of implementing intelligent systems that can reason in a way that mimics human reasoning. Topics include: syntax and semantics of common logic, description logic, modal epistemic logic; reasoning about uncertainties, beliefs, defaults and counterfactuals; reasoning within contexts; implementations of knowledge base and textual inference reasoning systems; and applications. Prerequisite: CS 5343. (3-0) Y

CS 6374 Computational Logic (3 semester credit hours) Deductive, inductive and abductive reasoning, logic-based knowledge representation and reasoning. Logic programming, constraint programming, and the Prolog language. Non-monotonic reasoning, answer set programming, and automating common sense reasoning. Applications of the above. Prerequisites: CS 5343. (3-0) Y

CS 6375 Machine Learning (3 semester credit hours) Algorithms for training perceptions and multi-layer neural nets: back propagation, Boltzmann machines, and self-organizing nets. The ID3 and the Nearest Neighbor algorithms. Formal models for analyzing learnability: exact identification in the limit and probably approximately correct (PAC) identification. Computational limitations of learning machines. Prerequisite: CS 5343. (3-0) Y

CS 6376 Parallel Processing (3 semester credit hours) Topics include parallel processing, parallel machine models, parallel algorithms for sorting, searching and matrix operations. Parallel graph algorithms. Prerequisite: CS 5343. (3-0) T

CS 6377 Introduction to Cryptography (3 semester credit hours) This course covers the basic aspects of modern cryptography, including block ciphers, pseudorandom functions, symmetric encryption, Hash functions, message authentication, number-theoretic primitives, public-key encryption, digital signatures and zero knowledge proofs. Prerequisites: CS 5333 and CS 5343 and ENCS majors only. (3-0) T

CS 6378 Advanced Operating Systems (3 semester credit hours) Concurrent processing, inter-process communication, process synchronization, deadlocks, introduction to queuing theory and operational analysis, topics in distributed systems and algorithms, checkpointing, recovery, multiprocessor operating systems. Must have knowledge of C, UNIX, and Socket Programming. Prerequisites: CS 5343 and CS 5348 or equivalent. (3-0) S

CS 6380 Distributed Computing (3 semester credit hours) Topics include distributed algorithms, election algorithms, synchronizers, mutual exclusion, resource allocation, deadlocks, Byzantine agreement and clock synchronization, knowledge and common knowledge, reliability in distributed networks, and proving distributed programs correct. Prerequisite: CS 5348. (3-0) S

CS 6381 Combinatorics and Graph Algorithms (3 semester credit hours) Fundamentals of combinatorics and graph theory. Combinatorial optimization, optimization algorithms for graphs (max flow, shortest routes, Euler tour, Hamiltonian tour). Prerequisites: CS 5343 and CS 6363. (3-0) T

CS 6382 Theory of Computation (3 semester credit hours) Formal models of computation. Recursive function theory. Undecidability and incompleteness. Selected topics in theory of computation. Instructor consent required. (3-0) Y

CS 6384 Computer Vision (3 semester credit hours) Algorithms for extracting information from digital pictures. Particular topics include: analysis of motion in time varying image sequences, recovering depth from a pair of stereo images, image separation, recovering shape from textured images and shadows, object matching techniques, model based recognition, and the Hough transform. Prerequisite: CS 5343. (3-0) Y

CS 6385 (TE 6385) Algorithmic Aspects of Telecommunication Networks (3 semester credit hours) This is an advanced course on topics related to the design, analysis, and development of telecommunications systems and networks. The focus is on the efficient algorithmic solutions for key problems in modern telecommunications networks, in centralized and distributed models. Topics include: main concepts in the design of distributed algorithms in synchronous and asynchronous models, analysis techniques for distributed algorithms, centralized and distributed solutions for handling design and optimization problems concerning network topology, architecture, routing, survivability, reliability, congestion, dimensioning and traffic management in modern telecommunication networks. Prerequisites: CS 5343 and CS 5348 and (CS 3341 or ENGR 3341 or equivalent). (3-0) Y

CS 6386 Telecommunication Software Design (3 semester credit hours) Programming with sockets and remote procedure calls, real time programming concepts and strategies. Operating system design for real time systems. Encryption, file compression, and implementation of fire walls. An in-depth study of TCP/IP implementation. Introduction to discrete event simulation of networks. Prerequisite: CS 5390. (3-0) Y

CS 6390 Advanced Computer Networks (3 semester credit hours) Survey of recent advancements in high-speed network technologies. Application of quantitative approach to the study of broadband integrated networks including admission control, access control, and quality of service guarantee. Prerequisite: CS 5390. (3-0) S

CS 6391 Optical Networks (3 semester credit hours) Enabling technologies for optical networks. Wavelength-division multiplexing. Broadcast-and-select optical networks. Wavelength-routed optical networks. Virtual topology design. Routing and wavelength assignment. Network control and management. Protection and restoration. Wavelength conversion. Traffic grooming. Photonic packet switching. Optical burst switching. Survey of recent advances in optical networking.

Prerequisites: CS 5390 and (CS 6352 or CS 6385 or CS 6390). (3-0) Y

CS 6392 Mobile Computing Systems (3 semester credit hours) Topics include coping with mobility of computing systems, data management, reliability issues, packet transmission, mobile IP, end-to-end reliable communication, channel and other resource allocation, slot assignment, routing protocols, and issues in mobile wireless networks (without base stations). Prerequisite: CS 6378 or CS 6390. (3-0) Y

CS 6396 (CE 6308 and EEDG 6308) Real-Time Systems (3 semester credit hours) Introduction to real-time applications and concepts. Real-time operating systems and resource management. Specification and design methods for real-time systems. System performance analysis and optimization techniques. Project to specify, analyze, design, implement and test small real-time system. Prerequisite: CS 5348. (3-0) R

CS 6397 Synthesis and Optimization of High-Performance Systems (3 semester credit hours) A comprehensive study of high-level synthesis and optimization algorithms for designing high performance systems with multiple CPUs or functional units for critical applications such as Multimedia, Signal processing, Telecommunications, Networks, and Graphics applications, etc. Topics including algorithms for architecture-level synthesis, scheduling, resource binding, real-time systems, parallel processor array design and mapping, code generations for DSP processors, embedded systems and hardware/software codesigns. Prerequisite: CS 5343. (3-0) T

CS 6V81 Independent Study in Computer Science (1-9 semester credit hours) May be repeated for credit. Prerequisite: ENCS majors only and instructor consent required. ([1-9]-0) S

CS 6V98 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. Prerequisite: ENCS majors only. ([3-9]-0) S

CS 7301 (SE 7301) Recent Advances in Computing (3 semester credit hours) Advanced topics and publications will be selected from the theory, design, and implementation issues in computing. May be repeated for credit as topics vary. Prerequisites: ENCS majors only and instructor consent required. (3-0) Y

CS 8V02 Topics in Computer Science (1-6 semester credit hours) Pass/Fail only. May be repeated for credit (9 semester credit hours maximum). Instructor consent required. Prerequisite: ENCS majors only. ([1-6]-0) S

CS 8V07 Research (1-9 semester credit hours) Open to students with advanced standing subject to approval of the graduate advisor. Pass/Fail only. May be repeated for credit. Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

CS 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

Engineering and Computer Science COOP

ECSC 5177 CS IPP Assignment (1 semester credit hour) Work in an approved, supervised, computer science position. Students will complete an IPP Work Report including a written Narrative focusing on the accomplishments and learning gained through the IPP experience. Pass/Fail only. May be repeated for credit. Instructor consent required. (1-0) Y

ECSC 5179 ENG IPP Assignment (1 semester credit hour) Work in an approved, supervised, engineering position. Students will complete an IPP Work Report including a written Narrative focusing on the accomplishments and learning gained through the IPP experience. Pass/Fail only. May be repeated for credit. Instructor consent required. (1-0) Y

Electrical Engineering: Biomedical Applications of Electrical Engineering

EEBM 6373 (BMEN 6373) Physiology and Immunology for Engineers (3 semester credit hours) This course provides an introduction to human physiology for engineers. Topics include antibodies, antigen-antibody interactions, HLA 1 & 2, complement, T and B cells, immunoregulation, tumor Immunobiology, basic and applied neuroscience, sensory systems, and neural interfaces. (3-0) Y

EEBM 6374 (BMEN 6374) Genes, Proteins and Cell Biology for Engineers (3 semester credit hours) This course provides an introduction to principles of modern molecular and cellular biology for engineers and other non-life scientists. Topics include genes, protein structure and function, organization of cells and cellular trafficking. (3-0) Y

EEBM 6380 (BMEN 6380) Introduction to Cellular Microscopy (3 semester credit hours) Image formation, diffraction, labeling techniques, fluorescence and image processing techniques will be introduced. (3-0) R

EEBM 6381 (BMEN 6381) Advanced Concepts in Microscopy (3 semester credit hours) Continuation of EEBM 6380, with emphasis on advanced approaches such as vectorial diffraction, stochastic aspects of image formation and analysis. Prerequisite: BMEN 6380 or EEBM 6380 or instructor consent required. (3-0) R

EEBM 7V87 Special Topics in Biomedical Applications of Electrical Engineering (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

Electrical Engineering: Control Systems

EECS 5375 (BMEN 5375) Introduction to Robotics (3 semester credit hours) Fundamentals of robotics, rigid motions, homogeneous transformations, forward and inverse kinematics, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control. Prerequisites: ENGR 2300 and (EE 4310 or BMEN 4310 or MECH 4310) or equivalent. Lab fee of $30 required. (2-3) Y

EECS 6302 (BMEN 6302 and MECH 6317 and SYSM 6302) Dynamics of Complex Networks and Systems (3 semester credit hours) Design and analysis of complex interconnected networks and systems. Basic concepts in graph theory; Eulerian and Hamiltonian graphs; traveling salesman problems; random graphs; power laws; small world networks; clustering; introduction to dynamical systems; stability; chaos and fractals. (3-0) Y

EECS 6323 (MECH 6323 and SYSE 6323) Robust Control Systems (3 semester credit hours) Theory, methodology, and software tools for the analysis and design of model-based control systems with multiple actuators and multiple sensors. Control oriented model parameterizations and modeling errors. Definitions and criteria for robust stability and performance. Optimal synthesis of linear controllers. The loop shaping design method. Methods to simplify the control law. Mechatronic design examples. Prerequisite: MECH 4310 or equivalent and MECH 6300 or EECS 6331 or SYSM 6307 or equivalent. (3-0) T

EECS 6324 (BMEN 6324 and MECH 6324 and SYSE 6326) Robot Control (3 semester credit hours) Dynamics of robots; methods of control; force control; robust and adaptive control; feedback linearization; Lyapunov design methods; passivity and network control; control of multiple and redundant robots; teleoperation. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307. (3-0) T

EECS 6331 (MECH 6300 and SYSM 6307) Linear Systems (3 semester credit hours) State space methods of analysis and design for linear dynamical systems. Coordinate transformations and tools from advanced linear algebra. Controllability and observability. Lyapunov stability analysis. Pole assignment, stabilizability, detectability. State estimation for deterministic models, observers. Introduction to the optimal linear quadratic regulator problem. Prerequisites: ENGR 2300 and EE 4310 or MECH 4310 or equivalent. (3-0) Y

EECS 6336 (BMEN 6388 and MECH 6313 and SYSE 6324) Nonlinear Systems (3 semester credit hours) Equilibria, phase portraits, linearization of nonlinear systems; periodic solutions; Poincare-Bendixson theorem; fundamental existence and uniqueness theorem for ODEs; Lyapunov stability theory; Invariance principle and LaSalle's theorem; converse theorems; singular perturbations; center manifold theorem; differential geometric tools, feedback linearization, input-output linearization, output injection, output tracking, passivity-based control; backstepping. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307 or equivalent. (3-0) T

EECS 7V90 Special Topics in Control Systems (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

Electrical Engineering: Circuits and Systems

EECT 6325 (CE 6325) VLSI Design (3 semester credit hours) Introduction to MOS transistors. Analysis of the CMOS inverter. Combinational and sequential design techniques in VLSI; issues in static, transmission gate and dynamic logic design. Design and layout of complex gates, latches and flip-flops, arithmetic circuits, memory structures. Low power digital design. The method of logical effort. CMOS technology. Use of CAD tools to design, layout, check, extract and simulate a small project. Prerequisites: EE 3301 and EE 3320 or equivalent. (3-0) S

EECT 6326 Analog Integrated Circuit Design (3 semester credit hours) Further treatment on the use of MOSFET and BJT large signal and small signal models to analyze and design analog integrated circuits. Topics include advanced current mirrors, references, frequency response of single-stage and differential amplifiers, stability and compensation of amplifiers, design of two-stage amplifiers, common mode feedback, and introduction of noise analysis. Use of CAD tools to simulate and design analog integrated circuits. Prerequisite: EE 4340. (3-0) S

EECT 6378 Power Management Circuits (3 semester credit hours) This course introduces different circuits related to power management systems. Topics include analysis and design of voltage references, magnetics, and different dc-dc converters including: switched-mode power converters, linear regulators and switched-capacitor charge pumps. Use of CAD tools to design and simulate power management circuits. Prerequisite: EECT 6326 or equivalent. (3-0) Y

EECT 6379 Energy Harvesting, Storage and Powering for Microsystems (3 semester credit hours) This course studies the electrical characteristics of various renewable energy sources and the corresponding approaches on harvesting and storage, with emphasis on the imposed requirements of microscale dimension. They are followed by the discussion on power conditioning and cross-layer energy/power management with circuit implementations. Prerequisite: EE 3311 or equivalent. (3-0) Y

EECT 7325 (CE 7325) Advanced VLSI Design (3 semester credit hours) Advanced topics in VLSI design covering topics beyond the first course (EECT 6325). Topics include: use of high-level design, synthesis, and simulation tools, clock distribution and routing problems, (a)synchronous circuits, low-power design techniques, study of various VLSI-based computations, systolic arrays, etc. Discussions on current research topics in VLSI design. Prerequisite: EECT 6325 or equivalent. (3-0) R

EECT 7326 Advanced Analog Integrated Circuit Design (3 semester credit hours) Advanced topics in analog design including a rigorous treatment of noise, feedback and distortion in analog circuits. Selected topics from other advanced topics such as continuous-time filter, oscillator, phase-locked loop (PLL) and delay-locked loop (DLL) are also covered. Prerequisite: EECT 6326. (3-0) T

EECT 7327 Data Converters (3 semester credit hours) Data converter circuits in modern mixed-signal VLSI systems. Topics include sampling, switched-capacitor amplifiers and integrators, sample-and-hold circuits, voltage comparators, Nyquist-rate and oversampling converters. Prerequisites: EECT 6325 and EECT 6326. (3-0) T

EECT 7V88 Special Topics in Circuits and Systems (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

Electrical Engineering: Digital Systems

EEDG 5325 (CE 5325) Hardware Modeling Using HDL (3 semester credit hours) This course introduces students to hardware description languages (HDL) beginning with simple examples and describing tools and methodologies. It covers the language, dwelling on fundamental simulation concepts. Students are also exposed to the subset of HDL that may be used for synthesis of custom logic. HDL simulation and synthesis labs and projects are performed using commercial and/or academic VLSI CAD tools. Prerequisite: EE 3320 or equivalent. (3-0) T

EEDG 6301 (CE 6301) Advanced Digital Logic (3 semester credit hours) Modern design techniques for digital logic. Logic synthesis and design methodology. Link between front-end and back-end design flows. Field programmable gate arrays and reconfigurable digital systems. Introduction to testing, simulation, fault diagnosis and design for testability. Prerequisites: EE 3320 or equivalent and background in VHDL/Verilog. (3-0) T

EEDG 6302 (CE 6302) Microprocessor and Embedded Systems (3 semester credit hours) Design of microprocessor based systems including I/O and interface devices. Programming of micro-controllers and embedded systems. Microprocessor architectures. Use of emulators and other sophisticated test equipment. Extensive laboratory work. Lab fee of $30 required. Prerequisites: EE 4304 or equivalent and background in VHDL/Verilog. (2-3) Y

EEDG 6303 (CE 6303) Testing and Testable Design (3 semester credit hours) Techniques for detection of failures in digital circuits and systems. Fault modeling and detection. Functional testing and algorithms for automatic test pattern generation (ATPG). Design of easily testable digital systems. Techniques for introducing built-in self test (BIST) capability. Test of various digital modules, such as PLA's, memory circuits, datapath, etc. Prerequisites: EE 3320 or equivalent and background in VHDL/Verilog. (3-0) Y

EEDG 6304 (CE 6304 and CS 6304) Computer Architecture (3 semester credit hours) Trends in processor, memory, I/O and system design. Techniques for quantitative analysis and evaluation of computer systems to understand and compare alternative design choices in system design. Components in high performance processors and computers: pipelining, instruction level parallelism, memory hierarchies, and input/output. Students will undertake a major computing system analysis and design project. Must have an understanding of C/C++. Prerequisite: CS 2340 or EE 4304. (3-0) Y

EEDG 6306 (CE 6306) Application Specific Integrated Circuits Design (3 semester credit hours) This course discusses the design of application specific integrated circuits (ASIC). Specific topics include: VLSI system design specification, ASIC circuit structures, synthesis, and implementation of an ASIC digital signal processing (DSP) chip. Prerequisite: EE 3320. (3-0) Y

EEDG 6308 (CE 6308 and CS 6396) Real-Time Systems (3 semester credit hours) Introduction to real-time applications and concepts. Real-time operating systems and resource management. Specification and design methods for real-time systems. System performance analysis and optimization techniques. Project to specify, analyze, design, implement and test small real-time system. Prerequisite: CS 5348. (3-0) R

EEDG 6309 (CE 6309) Applications of Machine Learning in Semiconductor IC Manufacturing and Test (3 semester credit hours) Fundamentals of machine learning, including regression, classification, feature extraction, feature selection, synthetic training set enhancement, boosting and curse of dimensionality; test cost reduction via test compaction, alternate test, adaptive test and effectiveness metrics; wafer-level spatial and spatio-temporal correlation modeling, process variation decomposition, process monitoring, outlier detection yield prediction; post-manufacturing tuning and post-deployment calibration of analog/RF ICs; security and trust assessment, including hardware Trojan detection, counterfeit IC identification, and fab-of-origin attestation. Experience with Machine Learning methods and software desirable but not required. Prerequisite: CE 6301 or EEDG 6301 or CE 6303 or EEDG 6303 or CE 6325 or EECT 6325 or EECT 6326. (3-0) Y

EEDG 6310 (CE 6310) Hardware Security (3 semester credit hours) Theory of cryptography for security, an overview of both classical and emerging attack methods and methodologies and possible defenses against them with respect to silicon-on-chip security, side-channel attacks, hardware trojans, physically unclonable functions, IC counterfeit protection, and hardware-based malware detection. (3-0) Y

EEDG 6312 (CE 6312) Computing with Emerging Technologies (3 semester credit hours) Integration of emerging technologies in novel computing systems. Relevant devices include various spintronic devices, carbon nanotubes, graphene, memristors, and multi-gate FETs. Relevant computational functions include Boolean logic, as well as neuromorphic, threshold, stateful, quantum, and stochastic computing systems. (3-0) Y

EEDG 6330 (CE 6330) Applied Cryptography (3 semester credit hours) This course presents a wide range of cryptographic principles and their implementation in software/hardware. This includes: security properties; block and stream ciphers, their basic implementations, and various ways to attack them including side-channel attacks; public-key schemes using number/group-theoretic techniques; advanced protocols; and resilient implementation techniques. Basic familiarity with algorithms, probability, and algebra needed. Credit cannot be received for both CS 6377 and (CE 6330 or EEDG 6330). Prerequisite: ENCS majors only. (3-0) Y

EEDG 6331 (CE 6331) High-Level Synthesis: Design and Verification (3 semester credit hours) Facilitate the design of dedicated hardware using higher levels of abstraction (ANSI-C, C++ or SystemC) instead of hardware description languages like Verilog or VHDL. Theory of HLS process is comprehensively studied including: technology independent optimizations, resource allocation, scheduling, and binding stages. Students will design different types of hardware accelerators using HLS and learn how to design and verify complete hardware systems using only C. Course projects may include, but are not limited to: Building an automated HLS design space explorer, design of neural networks and building complete systems in C. Commercially available EDA tools will be used during the course. Prerequisite: EE 3320 or equivalent, C/C++. (3-0) Y

EEDG 6370 (CE 6370) Design and Analysis of Reconfigurable Systems (3 semester credit hours) Introduction to reconfigurable computing, programmable logic: FPGAS, CPLDs, CAD issues with FPGA based design, reconfigurable systems: emulation, custom computing, and embedded application based computing, static and dynamic hardware, evolutionary design, software environments for reconfigurable systems. Prerequisite: EE 3320 or equivalent. (3-0) R

EEDG 6375 (CE 6375) Design Automation of VLSI Systems (3 semester credit hours) This course deals with various topics related to the development of CAD tools for VLSI systems design. Algorithms, data structures, heuristics and design methodologies behind CAD tools. Design and analysis of algorithms for layout, circuit partitioning, placement, routing, chip floor planning, and design rule checking (DRC). Introduction to CAD algorithms for RTL and behavior level synthesis, module generators, and silicon compilation. (3-0) Y

EEDG 7V81 Special Topics in Digital Systems (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

Electrical Engineering - Graduate

EEGR 6316 Fields and Waves (3 semester credit hours) Study of electromagnetic wave propagation beginning with Maxwell's equations; reflection and refraction at plane boundaries; guided wave propagation; radiation from dipole antennas and arrays; reciprocity theory; basics of transmission line theory and waveguides. Prerequisite: EE 4301 or equivalent. (3-0) Y

EEGR 6381 (MECH 6391) Computational Methods in Engineering (3 semester credit hours) Numerical techniques and their applications in engineering. Topics will include: numerical methods of linear algebra, interpolation, solution of nonlinear equations, numerical integration, Monte Carlo methods, numerical solution of ordinary and partial differential equations, and numerical solution of integral equations. Prerequisites: ENGR 2300 and ENGR 3300 or equivalent, and knowledge of a scientific programming language. (3-0) R

EEGR 6397 Convex Optimization (3 semester credit hours) Introduction to convex optimization, with a focus on recognizing and solving convex optimization problems that arise in applications. Convex sets, convex functions, operations preserving convexity, convex optimization problems, quasi-convex, linear, and quadratic optimization, geometric and semi-definite programming, generalized inequalities, vector optimization, the Lagrange dual problem, optimality conditions, sensitivity analysis, applications in approximation and fitting, statistical estimation, and geometric problems, overview of numerical linear algebra, descent methods, Newton's method, handling equality constraints, introduction to interior point methods. (3-0) R

EEGR 6V88 Special Topics in Electrical Engineering (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

EEGR 6V98 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

EEGR 8V40 Individual Instruction in Electrical Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-6]-0) R

EEGR 8V70 Research in Electrical Engineering (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) R

EEGR 8V99 Dissertation (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

Electrical Engineering: Solid State Devices & Micro Sys Fabric

EEMF 5383 (PHYS 5383) Plasma Technology (3 semester credit hours) Hardware oriented study of useful laboratory plasmas. Topics will include vacuum technology, gas kinetic theory, basic plasma theory and an introduction to the uses of plasmas in various industries. (3-0) T

EEMF 6315 Advanced Electronic Packaging Technologies (3 semester credit hours) Electrical design and analysis- signal and power integrity, thermal designs at chip-package-board level, cooling solutions, thermo-mechanical designs and interface stress analysis. Reliability testing and failure modes. Electronic packaging materials, properties and characterization, chip-package interconnection technologies, wafer scale and 3D packaging, encapsulation techniques, multi-chip modules and system in package-heterogeneous integration technologies. Design for performance, reliability, and manufacturing. (3-0) Y

EEMF 6319 Quantum Physical Electronics (3 semester credit hours) Quantum-mechanical foundation for study of nanometer-scale electronic devices. Principles of quantum physics, stationary-state eigenfunctions and eigenvalues for one-dimensional potentials, interaction with the electromagnetic field, electronic conduction in solids, applications of quantum structures. Prerequisite: ENGR 3300 or equivalent. (3-0) Y

EEMF 6320 (MSEN 6320) Fundamentals of Semiconductor Devices (3 semester credit hours) Semiconductor material properties, band structure, equilibrium carrier distributions, non-equilibrium current-transport processes, and recombination-generation processes. Corequisite: EEMF 6319 or equivalent. (3-0) Y

EEMF 6321 (MSEN 6321) Active Semiconductor Devices (3 semester credit hours) The physics of operation of active devices will be examined, including p-n junctions, bipolar junction transistors and field-effect transistors: MOSFETs, JFETS, and MESFETS. Active two-terminal devices and optoelectronic devices will be presented. Recommended corequisite: EEMF 6320 or MSEN 6320. (3-0) Y

EEMF 6322 (MECH 6348 and MSEN 6322) Semiconductor Processing Technology (3 semester credit hours) Modern techniques for the manufacture of semiconductor devices and circuits. Techniques for both silicon and compound semiconductor processing are studied as well as an introduction to the design of experiments. Topics include: wafer growth, oxidation, diffusion, ion implantation, lithography, etch and deposition. (3-0) T

EEMF 6324 (MSEN 6324) Electronic, Optical and Magnetic Materials (3 semester credit hours) Foundations of materials properties for electronic, optical and magnetic applications. Electrical and thermal conduction, elementary quantum physics, modern theory of solids, semiconductors and devices, dielectrics, magnetic and optical materials properties. Prerequisite: MSEN 5300 or equivalent. (3-0) T

EEMF 6327 (MSEN 6327) Semiconductor Device Characterization (3 semester credit hours) This course will describe the theoretical and practical considerations associated with the most common electrical and reliability characterization techniques used in the semiconductor industry. Prerequisite: (EEMF 6320 or MSEN 6320 or equivalent) or instructor consent required. (3-0) T

EEMF 6348 (MECH 6341 and MSEN 6348) Lithography and Nanofabrication (3 semester credit hours) Study of the principles, practical considerations, and instrumentation of major lithography technologies for nanofabrication of devices and materials. Advanced photolithography, electron beam lithography, nanoimprint lithography, x-ray lithography, ion beam lithography, soft lithography, and scanning probe lithography, basic resist and polymer science, applications in nanoelectronic and biomaterials. (3-0) Y

EEMF 6372 Semiconductor Process Integration (3 semester credit hours) The integration of semiconductor processing technology to yield integrated circuits. The course will emphasize MOSFET design based upon process integration, in particular as it applies to short channel devices of current interest. Process simulation will be used to study diffusion, oxidation, and ion implantation. (3-0) R

EEMF 6382 (MECH 6347 and MSEN 6382) Introduction to MEMS (3 semester credit hours) Study of micro-electro-mechanical devices and systems and their applications. Microfabrication techniques and other emerging fabrication processes for MEMS are studied along with their process physics. Principles of operations of various MEMS devices such as mechanical, optical, thermal, magnetic, chemical/biological sensors/actuators are studied. Topics include: bulk/surface micromachining, LIGA, microsensors and microactuators in multiphysics domain. (3-0) T

EEMF 6383 (MECH 6383 and PHYS 6383) Plasma Science (3 semester credit hours) Theoretically oriented study of plasmas. Topics to include: fundamental properties of plasmas, fundamental equations (kinetic and fluid theory, electromagnetic waves, plasma waves, plasma sheaths), plasma chemistry and plasma diagnostics. Prerequisite: EEGR 6316 or equivalent. (3-0) T

EEMF 7320 Advanced Semiconductor Device Theory (3 semester credit hours) Quantum mechanical description of fundamental semiconductor devices; carrier transport on the submicron scale; heterostructure devices; quantum-effect devices. Prerequisites: EEMF 6320 and EEMF 6321. (3-0) R

EEMF 7V82 Special Topics in Microelectronics (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

Electrical Engineering: Optical Devices, Materials & Systems

EEOP 6310 Optical Communication Systems (3 semester credit hours) Operating principles of optical communications systems and fiber optic communication technology. Characteristics of optical fibers, laser diodes, and laser modulation, laser and fiber amplifiers, detection, demodulation, dispersion compensation, and network topologies. System topology, star network, bus networks, layered architectures, all-optical networks. Prerequisite: EE 3350 or equivalent. (3-0)

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EEOP 6311 Photonic Devices and Integration (3 semester credit hours) This course will discuss the design and operation of passive and active semiconductor optical devices such as waveguides, lasers and modulators, the materials used and their advantages and disadvantages, the compromises needed for integration of devices, the processes used in integration, the subsystems and systems that can be achieved through integration. (3-0) Y

EEOP 6313 Semiconductor Opto-Electronic Devices (3 semester credit hours) Physical principles of semiconductor optoelectronic devices: optical properties of semiconductors, optical gain and absorption, wave guiding, laser oscillation in semiconductors, LEDs, physics of detectors, applications. Prerequisite: EE 3310 or equivalent. (3-0) R

EEOP 6314 Principles of Fiber and Integrated Optics (3 semester credit hours) Theory of dielectric waveguides, modes of planar waveguides, strip waveguides, optical fibers, coupled-mode formalism, directional couplers, diffractive elements, switches, wavelength-tunable filters, polarization properties of devices and fibers, step and graded-index fibers, devices for fiber measurements, fiber splices, polarization properties, and fiber systems. Prerequisites: ENGR 3300 and EE 4301 or equivalent. (3-0) T

EEOP 7340 Optical Network Architectures and Protocols (3 semester credit hours) Introduction to optical networks. The ITU Optical Layer. First-generation optical networks. Second-generation optical networks. Standards, e.g., OTN, SONET/SDH, GMPLS, PCEP. Broadcast and select networks. The lightpath concept. Wavelength routing networks. Flexible grid networks. Virtual topology design. Software Defined Networking in optical networks. Advanced solutions and test beds. (3-0) R

Electrical Engineering: Power Electronics and Energy Systems

EEPE 6354 Power Electronics (3 semester credit hours) Power Electronics and applications; Review of power devices including wide band gap devices. Harmonics and power factor in non-sinusoidal systems. AC-DC Phase Controlled Thyristor Converters. DC-DC converters: Buck, Boost, and Buck-Boost converters. Flyback, Cuk, and Full bridge converters. DC-AC Inverters: Square wave, Sinusoidal, Space Vector PWM, and current regulated inverters. Introduction to Active Rectifiers, Resonant Converters, and Multi-level converters. Introduction to AC motor Drives Systems and control. Prerequisite: EE 3311. (3-0) Y

EEPE 6356 Adjustable Speed Motor Drives (3 semester credit hours) Steady state and dynamic performance of electric machines - induction, synchronous, reluctance, and PM machines. Two axis models of AC machines and AC drives. Control characteristics of electric machines and control methodologies. Direct torque and flux control and current regulated controllers. Field orientation control techniques - stator flux, rotor flux, and air gap flux orientation. Introduction to fault tolerant and sensorless control of machines. Prerequisite: EE 3311. (3-0) Y

EEPE 6357 Control, Modeling and Simulation in Power Electronics (3 semester credit hours)

Principles of modeling and fundamentals of controller design for inverters, and switching dc-dc power converters will be discussed with an emphasis on generalized averaging methods. Special attention will be given to analysis and design of regulated power supplies for low power and medium power level supplies. An introduction to nonlinear phenomenon in power electronic systems and adjustable speed motor drives will be included. Finally analysis and design of multi-converter systems will be discussed and the use of advanced control methods such as Feedback linearization and sliding mode control in such systems will be explored. Prerequisite: EE 3311. (3-0) Y

EEPE 6358 Electrification of Transportation (3 semester credit hours) Introduction to electric and hybrid vehicles. Hybrid vehicle architectures - series, parallel and plug-in hybrid vehicle architectures - range extender and full hybrid systems. Propulsion system analysis, powertrain component sizing, and vehicle simulation. Energy requirements, energy storage devices, and fuel cell vehicles. Power electronic converters for electric and hybrid vehicles. Energy management and control strategies. Characteristics of commercially available hybrid vehicles. Introduction to more electric aircraft and architectures. Marine electric propulsion system. Prerequisite: EEPE 6354. (3-0) T

EEPE 6359 Renewable Energy Systems and Distributed Power Generation Systems (3 semester credit hours) Fundamentals of energy and sustainability. Interconnection of energy and environment. Renewable energy sources and availability: wind, solar, and fuel cell systems. Converters and controllers for integration of renewable energy sources. Solar and wind energy system design. Hybrid power generation systems. Smart grid system. Prerequisite: EEPE 6354. (3-0) T

EEPE 6398 General Theory of Electric Machines (3 semester credit hours) Fundamentals of electromechanical energy conversion, operating time constants, and dynamic operation of electric machinery. The theory and models of synchronous generators transient operations. Fundamentals of reference frame theory in multi-phase systems and its application to permanent magnet synchronous machines, wound rotor synchronous machines, induction machines, and synchronous reluctance machines. Electric machines operations using reluctance torque including steady state and transient operation of salient pole synchronous machines, interior permanent magnet synchronous motors and switched reluctance machines. (3-0) Y

EEPE 7354 Advanced Power Converters (3 semester credit hours) Pulse width modulation of converters and inverters. Space vector PWM strategies. Soft switching converters. High frequency resonant converters. Power factor correction rectifiers and distributed power systems. Active rectifiers. Multi-level converters. Matrix converters. Multiple input converters. (3-0) T

EEPE 7356 Computer Aided Design of Electric Machines (3 semester credit hours) Principles of force generation and distribution of electromagnetic forces within induction, permanent magnet synchronous, and reluctance machines. Introduction to finite element analysis of electric machinery. Electromagnetic, structural, and thermal fields in electric machines. Multi-physics analysis of electric machines. Optimization methodologies in multi-objective problems. Applications of artificial intelligence methods for optimal design of electric machinery. Prerequisite:

EEPE 6356. (3-0) T

EEPE 7V91 Special Topics in Power Electronics (1-6 semester credit hours) Advanced power electronics and drives related topics relevant to the needs for research in power/energy systems. May be repeated for credit as topics vary (12 semester credit hours maximum). Prerequisite: EEPE 6354. ([1-6]-0) R

Electrical Engineering: RF & Microwave Engineering

EERF 6311 RF and Microwave Circuits (3 semester credit hours) Analysis and design of RF and microwave circuits. Topics include impedance matching, network theory, S-parameters, transmission line media (waveguide, coax, microstrip, stripline, coplanar waveguide, etc.) and passive component design (power dividers, couplers, switches, attenuators, phase shifters, etc.). Industry-standard microwave CAD tools will be used. Prerequisite: EE 4368 or equivalent. (3-0) R

EERF 6330 RF Integrated Circuit Design (3 semester credit hours) Introduction to RF and wireless systems; basic concepts of RF design: linearity, distortion, (P1dB, IIP3), sensitivity, noise figure; RF passives: Q-factors, impedance transformation, matching network; transceiver architectures: Receivers - Heterodyne, direct down-conversion, image reject receivers, direct conversion transmitter, two-step transmitter; low noise amplifier design; mixer design; oscillator design; basic architectures of power amplifiers. Industry-standard CAD tools will be used for design projects. Prerequisite: EE 4340. (3-0) Y

EERF 6340 Active Microwave Design Laboratory (3 semester credit hours) Design of linear and non-linear microwave active circuits. Theory and design procedures are comprehensively studied including: component characterization, biasing, linear and non-linear analysis. Students will design, fabricate, and characterize several circuit types to demonstrate mastery of design procedures. Course projects may include, but are not limited to: low-noise amplifiers, mixers, VCOs, and power amplifiers. Commercially available CAD tools will be used for design. Corequisite: EERF 6355 or EERF 6330. Prerequisites: EERF 6311 and EERF 6396. (2-1) R

EERF 6351 Computational Electromagnetics (3 semester credit hours) Review of Maxwell's equations; numerical propagation of scalar waves; finite-difference time-domain solutions of Maxwell's equations; numerical implementations of boundary conditions; numerical stability; numerical dispersion; absorbing boundary conditions for free space and waveguides; selected applications in telecommunications, antennas, microelectronics and digital systems. Prerequisite: EE 4301 or equivalent. (3-0) R

EERF 6355 RF and Microwave Amplifier Design (3 semester credit hours) Design of narrow band, and broadband amplifiers. Study of stability on amplifiers. Study of noise figure, noise parameters and noise sources. Low noise amplifier design. Study of distortion on amplifiers. Introduction to power amplifiers. Microwave amplifier design in integrated circuits. Prerequisite: EERF 6311 or equivalent. (3-0) R

EERF 6393 Microwave Power Amplifiers (3 semester credit hours) RF/Microwave transistor power amplifier (PA) applications and fundamental linear and non-linear performance objectives are studied such as: output power, efficiency, and distortion. Key amplifier classes and design topologies are studied. Students will complete CAD design projects to demonstrate mastery of relevant techniques. Prerequisite: EERF 6311 or equivalent. Corequisite: EERF 6355 or equivalent. (3-0) R

EERF 6394 Antenna Engineering and Wave Propagation (3 semester credit hours) Operating principles for microwave antennas used in modern wireless communications and radar systems. Instructor consent required. (3-0) T

EERF 6395 RF and Microwave Systems Engineering (3 semester credit hours) Review of RF and microwave systems, such as cellular, point-to-point radio, satellite, RFID and RADAR. Topics include: system architectures, noise and distortion, antennas and propagation, transmission lines and network analysis, active and passive components, modulation techniques and specification flowdown. Prerequisite: EE 4368 or equivalent. (3-0) R

EERF 6396 Microwave Design and Measurement (3 semester credit hours) This lecture and lab course covers the fundamentals of microwave component design and measurements, including vector impedance (scattering parameters), scalar measurements and spectrum analysis. Microwave components, such as filters, directional couplers, switches, amplifiers, and oscillators, will be designed and simulated with various CAD tools and then built and measured to compare performance with theory. Lab fee of $30 required. Prerequisite: EE 4368 or equivalent. (2-1) R

EERF 7V89 Special Topics in RF and Microwave Systems (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-[0-3]) R

Electrical Engineering: Signal Processing & Communications

EESC 6340 Introduction to Telecommunications Networks (3 semester credit hours) Circuit, message and packet switching. The hierarchy of the ISO-OSI Layers. The physical layer: channel characteristics, coding, and error detection. The data link control layer: retransmission strategies, framing, multiaccess protocols, e.g., Aloha, slotted Aloha, CSMA, and CSMA/CD. The network layer: routing, broadcasting, multicasting, flow control schemes. Corequisite: EESC 6349. (3-0) Y

EESC 6341 Information Theory (3 semester credit hours) Entropy and mutual information, lossless compression, channel capacity for discrete memoryless channels and Gaussian channels, capacity under fading and multiple-input multiple-output (MIMO) channels, the multiple-access channel, the broadcast channel, the Slepian-Wolf problem. Prerequisite: ENGR 3341. (3-0) R

EESC 6343 Detection and Estimation Theory (3 semester credit hours) Parameter estimation. Least-squares, mean-square-error, and minimum-variance estimators. Maximum A Posteriori (MAP) and Maximum-Likelihood (ML) estimators. Bayes estimation. Cramer- Rao lower bound. BLUE estimator and Wiener filtering. Hypothesis testing and data-driven classification algorithms.

Prerequisite: EESC 6349. (3-0) R

EESC 6344 Coding Theory (3 semester credit hours) Fundamentals of linear block codes, Hamming and Reed-Muller codes, LDPC codes and message passing decoding, cyclic codes, BCH and Reed-Solomon codes, convolutional codes, introduction to coded modulation. Prerequisite: EE 4360. (3-0) R

EESC 6349 (MECH 6312) Probability, Random Variables, and Statistics (3 semester credit hours) Probability theory, random variables, functions of random variables, random vectors, whitening transformation, law of large numbers, sample-mean estimator, confidence interval, likelihood ratio test, Chi-square test. (3-0) Y

EESC 6350 Signal Theory (3 semester credit hours) Signal processing applications and signal spaces, vector spaces, matrix inverses and orthogonal projections, four fundamental subspaces, least squares and minimum norm solutions, the SVD and principal component analysis, subspace approximation, infinite dimensional spaces, linear operators, norms, inner products and Hilbert spaces, projection theorems, spectral properties of Hermitian operators, Hilbert spaces of random variables, linear minimum variance estimation and the Levinson-Durbin algorithm, general optimization over Hilbert spaces, methods and applications of optimization. Prerequisite: EE 3302 or equivalent. (3-0) R

EESC 6352 Digital Communication Systems (3 semester credit hours) This course covers basic principles of digital communications. The topics include introduction to source coding, signal representations, various digital modulation and transmission schemes, demodulators and detectors, error performance evaluations, introduction to channel coding, link budget, channel capacity and system design considerations. Overviews of various communication systems and their applications are also presented Prerequisite: ENGR 3341 or equivalent. (3-0) Y

EESC 6353 Broadband Digital Communication (3 semester credit hours) Characterization of broadband wireline and wireless channels. MAP and ML detection. Intersymbol Interference (ISI) effects. Equalization methods to mitigate ISI including single- carrier and multi-carrier techniques. Multi-Input Multi-Output (MIMO) communication systems. Implementation issues including complexity, channel estimation, bias and decision delay. Real-world case studies from Digital Subscriber Lines (DSL) and wireless systems. Students work individually or in small teams on a project and present their findings to the class. Prerequisites: EESC 6349 and knowledge of MATLAB. (3-0) T

EESC 6360 Digital Signal Processing I (3 semester credit hours) Analysis of discrete time signals and systems, Z-transform, discrete Fourier transform, fast Fourier transform, analysis and design of digital filters. Prerequisite: EE 4361 or equivalent. (3-0) Y

EESC 6361 Digital Signal Processing II (3 semester credit hours) Continuation of EESC 6360. Includes advanced topics in signal processing such as: Digital filter structures, digital filter design and implementation methods, multirate digital signal processing, linear prediction and optimum filtering, spectral analysis and estimation methods. Prerequisite: EESC 6360. (3-0) T

EESC 6362 Introduction to Speech Processing (3 semester credit hours) Introduction to the fundamentals of speech signal processing and speech applications. Speech analysis and speech synthesis techniques, speech enhancement and speech coding techniques including ADPCM and linear-predictive based methods such as CELP. Prerequisite: EESC 6360. (3-0) Y

EESC 6363 Digital Image Processing (3 semester credit hours) Image formation, image sampling, 2D Fourier transform and properties, image wavelet transform, image enhancement in spatial and frequency domains, image restoration, color image processing, image segmentation, edge detection, morphological operations, object representation and description, introduction to image compression. Prerequisites: EE 4361 or equivalent and knowledge of C or MATLAB. (3-0) T

EESC 6364 Machine Learning and Pattern Recognition (3 semester credit hours) This course covers basic concepts and algorithms for pattern recognition and machine learning. Bayesian decision theory, parametric learning, non-parametric learning, linear regression, linear classifiers and support vector machine, kernel methods, data clustering, mixture models, component analysis, multilayer neural networks, deep learning with convolutional neural networks. Prerequisites: Knowledge of probability and knowledge of MATLAB or C. (3-0) T

EESC 6365 Adaptive Signal Processing (3 semester credit hours) Adaptive signal processing algorithms learn the properties of their environments. Transversal and lattice versions of the Least Mean Squares (LMS) and Recursive Least Squares (RLS) adaptive filter algorithms and other modern algorithms will be studied. These algorithms will be applied to network and acoustic echo cancellation, speech enhancement, channel equalization, interference rejection, beam forming, direction finding, active noise control, wireless systems, and others. Prerequisites: EESC 6349 and EESC 6360 and knowledge of matrix algebra. (3-0) T

EESC 6366 Speech and Speaker Recognition (3 semester credit hours) Introduction to concepts in automatic recognition methods for speech applications; the primary emphasis is for automatic speech recognition and speaker identification techniques. Topics include speech features for recognition, hidden Markov models (HMMs) for acoustic and language applications (speech recognition, dialect/language recognition), Gaussian mixture models (GMMs) for speaker characterization, robustness issues to address noise and channel conditions for automatic recognition. (3-0) Y

EESC 6367 Applied Digital Signal Processing (3 semester credit hours) Implementation of signal processing algorithms, real-time signal processing, fixed-point versus floating-point implementation, architecture of processors used for signal processing, software development tools, code optimization, application project. Lab fee of $30 required. Prerequisites: EE 4361 or equivalent and knowledge of C. (2-3) T

EESC 6368 (CE 6368) Multimodal Deep Learning (3 semester credit hours) Theory and applications in the field of multimodal deep learning. Robustness and performance of systems by considering cross-modal integration. Deep learning methods used for representation, translation, alignment, fusion, and co-learning of multimodal content. Multimodal embeddings and their applications. Use of deep learning solutions such as convolutional neural network (CNN), Long short-term memory (LSTM), and attention models to process multimodal data. Recommended Corequisite: EESC 6349.

Prerequisite: ENGR 3341 or equivalent. (3-0) T

EESC 6389 Wireless Communications Laboratory (3 semester credit hours) This lecture and lab course covers the fundamentals of wireless communication from the perspective of digital signal processing (DSP). Physical layer concepts such as linear modulation, demodulation, and orthogonal frequency division multiplexing; synchronization, channel estimation, equalization, and MIMO will be translated into practice with the help of software defined radio platforms. Lab fee of $30 required. Prerequisite: EE 3350 or equivalent. (2-3) Y

EESC 6390 Introduction to Wireless Communication Systems (3 semester credit hours) Principles, practice, and system overview of mobile systems. Modulation, demodulation, coding, encoding, and multiple-access techniques. Performance characterization of mobile systems. Prerequisite: EE 3350 or equivalent. (3-0) Y

EESC 6391 Signaling and Coding for Wireless Communication Systems (3 semester credit hours) Study of signaling and coding for wireless communication systems. Topics which will be covered include digital modulation schemes, digital multiple access technologies, their performance under wireless channel impairments, equalization, channel coding, interleaving, and diversity schemes. Prerequisites: EESC 6352 and EESC 6390. (3-0) T

EESC 6392 Propagation and Devices for Wireless Communications (3 semester credit hours) Mobile communication fundamentals, models of wave propagation, simulation of electromagnetic waves in the cellular environment, multipath propagation, compensation for fading, mobile and cell antenna designs, problems of interference and incompatibility, design of active and passive cellular components, comparison of analog and digital cellular designs. Prerequisites: EE 4301 or equivalent, and EESC 6390. (3-0) R

EESC 6395 Wireless Sensor Systems and Networks (3 semester credit hours) Sensor mote architecture and design. Sensor network types, architecture and protocol stack. Studies on and design of physical layer, data link layer, network layer, transport layer, and application layer. Time synchronization, localization, topology, mobility and task management issues in wireless sensor networks. Security and privacy issues. Case studies on applications. Recommended prerequisite: (CE 4390 or CS 4390) or equivalent. (3-0) T

EESC 7V85 Special Topics in Signal Processing (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

EESC 7V86 Special Topics in Wireless Communications (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

Mechanical Engineering

MECH 5300 (MSEN 5300 and PHYS 5376) Introduction to Materials Science (3 semester credit hours) This course provides an extensive overview of materials science and engineering and includes the foundations required for further graduate study in the field. Topics include chemical bonding, crystalline structures, imperfections and diffusion in solids, mechanical properties, strengthening and failure mechanisms, phase diagrams and transformations, corrosion and degradation of materials, metal alloys, ceramics, polymers, composites, as well as their electrical, thermal, magnetic, and optical properties. Quantitative analyses will be emphasized. (3-0) R

MECH 5370 Wind Energy Fluid Mechanics (3 semester credit hours) This course provides an introduction of the flow physics in wind turbine arrays. The main aerodynamic characteristics of a wind turbine rotor, the concept of the wind turbine wake and its evolution, characteristics of the wind field for different atmospheric conditions will be discussed for both horizontal and vertical axis wind turbines. Using conservation principles, simplified models to assess wind turbine performances will be derived such as the Blade Element Theory, power performance and the Betz limit. Computational methods for simulating wind turbine wakes, ranging from analytical wake models to more sophisticated CFD tools will be reviewed. The course will also encompass basic notions on experimental techniques to monitor wind turbine wakes through wind LiDARs and how to reproduce down-scaled experiments in a wind tunnel environment . (3-0) Y

MECH 5371 Extreme Applications in Fluid Mechanics (3 semester credit hours) What causes tornadoes, and what sustains their immensely-destructive evolution? Why do beads of water dance across lotus leaves, and how can some insects defy gravity by walking on water? Turbidity currents are violent soil-water jets that career down the walls of the ocean sea floor: what causes them? After the Deepwater Horizon oil spill, fluid dynamicists were able to accurately estimate the number of barrels of oil per day emanating from the ruptured pipe: how did they do this? Why are wing suits a precarious activity (no instructor demonstrations given). In this class, we will draw upon undergraduate-level mathematics and fluid dynamics to explain the mechanisms responsible for these (and other) extreme fluid flows. (3-0) R

MECH 5373 Thermal Management of Microelectronics (3 semester credit hours) To provide an introduction to thermal phenomena occurring in electronic equipment and to provide an understanding of how basic heat transfer principles can be applied to the thermal design of electronic packages. The course will commence with an introduction to the fundamentals of different heat transfer modes. The calculation of heat loads and temperature fields will be discussed using different cooling techniques. Includes parameter evaluation and design studies for single- and multi-chip modules, printed circuit board, and high-heat-flux cooling. Prerequisites: MECH 3320 and MECH 3351 and MECH 4310. (3-0) R

MECH 5V95 Topics in Mechanical Engineering (1-9 semester credit hours) Selected topics in mechanical engineering are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). Additional prerequisites may be required depending on the specific course topic. ([1-9]-0) R

MECH 6300 (EECS 6331 and SYSM 6307) Linear Systems (3 semester credit hours) State space methods of analysis and design for linear dynamical systems. Coordinate transformations and tools from advanced linear algebra. Controllability and observability. Lyapunov stability analysis. Pole assignment, stabilizability, detectability. State estimation for deterministic models, observers. Introduction to the optimal linear quadratic regulator problem. Prerequisites: ENGR 2300 and EE 4310 or MECH 4310 or equivalent. (3-0) Y

MECH 6303 Computer Aided Design (3 semester credit hours) This course provides an introduction to design principles and methodologies for geometrical modeling, curve and surface fitting in an automated environment, CAD/CAM simulation of manufacturing, and computer-aided solid modeling. Prerequisite: MECH 3305 or equivalent. (3-0) Y

MECH 6306 Continuum Mechanics (3 semester credit hours) This course provides an introduction to mechanics of continua within a rigorous mathematical framework. Topics of interest include tensor analysis, kinematics, analysis of deformation, analysis of stress, and constitutive equations. Other areas of discussion focus on material anisotropy, mechanical properties of fluids and solids, derivation of field equations, boundary conditions, and solutions of initial and boundary value problems for continua. Prerequisite: MECH 3351 or equivalent. (3-0) Y

MECH 6308 Haptics and Teleoperated Systems (3 semester credit hours) This course presents an introduction to haptic systems for virtual environments and teleoperation. Course topics include: human haptics, haptic devices (design, dynamics, control, and rendering), tactile haptic displays, and teleoperation (implementation, transparency, and stability). The course will include a laboratory component, as well as a final hands-on design project. The course is also designed to improve reading and understanding of academic papers related to haptics and teleoperation, as well as to improve individual presentation skills and team-work. Prerequisites: MECH 3350 or equivalent and MECH 4310 or equivalent. (2-3) R

MECH 6309 Intermediate Dynamics (3 semester credit hours) This course covers variational principles, the principle of least action, Lagrange's and Hamilton's equations. Holonomic and nonholonomic constraints will be imposed in dynamics analysis. This course also covers coupled and uncoupled multiple degree-of-freedom linear systems, rigid body dynamics, and gyroscopic effects. Prerequisites: (MECH 2420 or equivalent) and (MECH 2330 or equivalent) and (MECH 4310 or MECH 4340) or equivalent. (3-0) R

MECH 6311 Advanced Mechanical Vibrations (3 semester credit hours) Vibration phenomena of multi-degree-of-freedom discrete and continuous systems. Lagrange's equations of motion for discrete systems. Determination of natural frequencies and mode shapes of discrete and continuous systems. Passive vibration control method. Applications of finite element methods to analysis of mechanical vibrations. Prerequisite: MECH 4340 or equivalent. (3-0) T

MECH 6312 (EESC 6349) Probability, Random Variables, and Statistics (3 semester credit hours) Probability theory, random variables, functions of random variables, random vectors, whitening transformation, law of large numbers, sample-mean estimator, confidence interval, likelihood ratio test, Chi-square test. (3-0) Y

MECH 6313 (BMEN 6388 and EECS 6336 and SYSE 6324) Nonlinear Systems (3 semester credit hours) Equilibria, phase portraits, linearization of nonlinear systems; periodic solutions; Poincare-Bendixson theorem; fundamental existence and uniqueness theorem for ODEs; Lyapunov stability theory; Invariance principle and LaSalle's theorem; converse theorems; singular perturbations; center manifold theorem; differential geometric tools, feedback linearization, input-output linearization, output injection, output tracking, passivity-based control; backstepping. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307 or equivalent. (3-0) T

MECH 6314 (BMEN 6372 and SYSM 6306 Engineering Systems: Modeling and Simulation (3 semester credit hours) This course will present principles of computational modeling and simulation of systems. General topics covered include: parametric and non-parametric modeling; system simulation; parameter estimation, linear regression and least squares; model structure and model validation through simulation; and, numerical issues in systems theory. Techniques covered include methods from numerical linear algebra, nonlinear programming and Monte Carlo simulation, with applications to general engineering systems. Modeling and simulation software is utilized (MATLAB/SIMULINK). (3-0) Y

MECH 6316 (SYSE 6322) Digital Control of Automotive Powertrain Systems (3 semester credit hours) Digital control systems, discretization and design by equivalents. Input-output design and discrete-time state variable estimation and control. Introduction to various control problems in automotive powertrains. Application of digital control principles to automotive powertrains for internal combustion engine idle speed control and air-to-fuel ratio control. Prerequisite: A basic course in control systems at the undergraduate level. (3-0) T

MECH 6317 (BMEN 6302 and EECS 6302 and SYSM 6302) Dynamics of Complex Networks and Systems (3 semester credit hours) Design and analysis of complex interconnected networks and systems. Basic concepts in graph theory; Eulerian and Hamiltonian graphs; traveling salesman problems; random graphs; power laws; small world networks; clustering; introduction to dynamical systems; stability; chaos and fractals. (3-0) Y

MECH 6318 Engineering Optimization (3 semester credit hours) Basics of optimization theory, numerical algorithms, and applications in engineering. The course covers linear programming (simplex method) and nonlinear programming, as well as unconstrained methods (optimality conditions, descent algorithms and convergence theorems), and constrained minimization (Lagrange multipliers, Karush-Kuhn-Tucker conditions, active set, penalty and interior point methods). Non-gradient based optimization methods are briefly introduced. Applications in mechanical engineering design will be emphasized. Students will use Matlab's Optimization Toolbox to obtain practical experience with the material. (3-0) Y

MECH 6319 Dynamics and Control of MEMS (3 semester credit hours) This course provides a comprehensive overview of Microelectromechanical Systems (MEMS) devices and their control systems. It covers topics such as MEMS fabrication processes, Sensing and actuation techniques in MEMS, Modeling and system identification of MEMS dynamics, control, signal processing, and interface electronics design for MEMS, and a number of case studies including MEMS accelerometers, gyroscopes, force sensors, pressure sensors and nanopositioners. Prerequisites: (MECH 4310 or equivalent) and MECH 6300 or equivalents. (3-0) R

MECH 6323 (EECS 6323 and SYSE 6323) Robust Control Systems (3 semester credit hours) Theory, methodology, and software tools for the analysis and design of model-based control systems with multiple actuators and multiple sensors. Control oriented model parameterizations and modeling errors. Definitions and criteria for robust stability and performance. Optimal synthesis of linear controllers. The loop shaping design method. Methods to simplify the control law. Mechatronic design examples. Prerequisite: MECH 4310 or equivalent and MECH 6300 or EECS 6331 or SYSM

6307 or equivalent. (3-0) T

MECH 6324 (BMEN 6324 and EECS 6324 and SYSE 6326) Robot Control (3 semester credit hours) Dynamics of robots; methods of control; force control; robust and adaptive control; feedback linearization; Lyapunov design methods; passivity and network control; control of multiple and redundant robots; teleoperation. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307. (3-0) T

MECH 6325 (SYSE 6325) Optimal Estimation and Kalman Filter (3 semester credit hours) Theory, analysis, design, and implementation of Kalman filters are covered in this course together with real-world applications of the theory. Topics include a review of probability and random variables; random signals and random processes; response of linear systems to random signals; the Wiener filter; the discrete-time Kalman filter; continuous-time Kalman filter; prediction and smoothing; the extended Kalman filter; the ensemble Kalman filter; the unscented Kalman filter; case studies in GPS and GPS-aided inertial navigation, simultaneous localization and mapping (SLAM), and amplitude and phase estimation in dynamic mode atomic force microscopy (AFM). Prerequisite: MECH 6300 or instructor consent required. (3-0) R

MECH 6326 Optimal Control and Dynamic Programming (3 semester credit hours) Introduction to stochastic control, with applications taken from a variety of areas, including automatic control, engineering, supply-chain management, resource allocations, finance, etc. Markov chains and Markov decision processes, optimal policies and value functions with full state information for finite-horizon, infinite-horizon discounted, and average stage cost problems. Dynamic programming and Bellman equation, value iteration, policy iteration. Linear quadratic stochastic control. Approximate dynamic programming and model predictive control. Prerequisite: MECH 6300 or instructor consent required. (3-0) R

MECH 6327 Convex Optimization in Systems and Controls (3 semester credit hours) Introduction to convex optimization, with a focus on recognizing and solving convex optimization problems that arise in applications. Convex sets, functions, and optimization problems. Basic convex analysis. Least-squares, linear and quadratic programs, second-order cone programs, semidefinite programming. Optimality conditions, duality theory, theorems of alternative, and applications. Descent and interior-point methods. Applications in systems and control, including trajectory optimization, model predictive control, stability and control design via linear matrix inequalities, and semialgebraic techniques. (3-0) R

MECH 6328 Frequency-Domain Analysis and Design of Control Systems (3 semester credit hours) This course provides an introduction to the frequency-domain analysis tools and design methods for single-input linear feedback control systems, which will be valuable for control system design for practical applications in order to achieve the desirable performance and robustness. The topics covered in this course include: Nyquist stability criterion, stability margins on Nquist plot and Bode plot, Bode's gain-phase relationship, Frequency-domain compensator design, norms of signals and systems, internal stability, uncertainty and robustness, design constraints, loop shaping and design for performance, and model matching. (3-0) R

MECH 6330 Multiscale Design and Optimization (3 semester credit hours) Multi-scale systems consist of components from two or more length scales (nano, micro, meso, or macro-scales). The challenge is to make these components so they are conceptually and model-wise compatible with other-scale components with which they interface. This course covers the fundamental properties of scales, design theories, modeling methods and manufacturing issues which must be addressed in these systems. Examples include precision instruments, nanomanipulators, fiber optics, micro/nano-photonics, nanorobotics, MEMS, and carbon nano-tube assemblies. Prerequisite: MECH 6303. (3-0) T

MECH 6333 Materials Design and Manufacturing (3 semester credit hours) This course provides an in-depth analysis of design problems faced in the development and mass manufacture of advanced materials. This course will explore the interplay among mathematical modeling, CAD, mold creation and manufacturing processes for polymers, ceramics and metals. Tradeoffs among various thermomechanical properties, cost and aesthetics will be studied. (3-0) T

MECH 6334 Smart Materials and Structures (3 semester credit hours) Introduction to smart materials. Fundamental properties of smart materials including piezoelectric materials, shape memory alloys or polymers, conducting polymers, dielectric elastomers, and ionic polymer metal composites. Constitutive modeling of smart materials. Characterization techniques. Applications as sensors, actuators and in energy harvesting. (3-0) T

MECH 6335 (OPRE 6340) Flexible Manufacturing Strategies (3 semester credit hours) The use of automation in manufacturing is continuously increasing. This course covers the variety of types of flexible automation, including flexible manufacturing systems, integrated circuit fabrication and assembly, and robotics. Examples of international systems are discussed to show the wide variety of systems designs and problems. Strategic as well as economic justification issues are covered. (3-0) R

MECH 6337 (SYSM 6301) Systems Engineering, Architecture and Design (3 semester credit hours) Architecture and design of large-scale and decentralized systems from technical and management perspectives. Systems architectures, requirements analysis, design tradeoffs, and reliability through various case studies and multiple types of mathematical techniques. International standardization bodies, including INCOSE, engineering frameworks, processes, and tool support from both theoretical and practical perspectives. (3-0) Y

MECH 6338 Reliability-Based Design (3 semester credit hours) This course covers fundamentals of reliability theory (factor of safety versus reliability, modeling uncertainty, marginal/joint random variable distributions, design process uncertainty), simulation methods and integration, computational issues for correlated random variables and large scale problems, expansion techniques, second moment methods, reliability of structural systems (response surfaces, Fast Fourier Transform approach, series and parallel systems, system reliability), and reliability-based design optimization. Interdisciplinary engineering applications are included. (3-0) Y

MECH 6339 Multidisciplinary Design Optimization (3 semester credit hours) The objective of the course is a comprehensive introduction to the mathematical and algorithmic techniques for coupled analysis and optimization of multidisciplinary mechanical and aerospace engineering problems. The focus will be on computational methods for coupled fluid-structure interaction problems, ranging from reduced order models to full scale finite volume and finite element simulations. State-of-the-art research examples will be demonstrated in the class to develop practical insight on computational methods for engineering design. This enables the students to design advanced and complex engineering systems that are competitive in terms of performance, and have life-cycle value. At the end of the course, the student should be able to master most of the complex problems in engineering design with a deep understanding of the used optimization theory and the physics of the computational based engineering. Prerequisite: MECH 6318. (3-0) R

MECH 6341 (EEMF 6348 and MSEN 6348) Lithography and Nanofabrication (3 semester credit hours) Study of the principles, practical considerations, and instrumentation of major lithography technologies for nanofabrication of devices and materials. Advanced photolithography, electron beam lithography, nanoimprint lithography, x-ray lithography, ion beam lithography, soft lithography, and scanning probe lithography, basic resist and polymer science, applications in nanoelectronic and biomaterials. (3-0) Y

MECH 6342 Renewable Energy and Grid Integration (3 semester credit hours) This course will discuss renewable energy and energy efficiency systems modeling, design, and optimization. After examining the technological specifications of the most important renewable energy resources (e.g., wind energy, photovoltaics, and solar thermal power) and energy efficiency technologies (e.g., energy storage, home and building energy, electric vehicles), grid integration of renewable energy and energy efficiency technologies will be examined in detail. All of these concepts will be explored in great detail and reinforced through the completion of a semester long project, where the students will be solving problems of broad interest in a group setting. Students will use Matlab and R for project design. The course builds on prerequisite knowledge in engineering system design, engineering mathematics, probability and statistics, and optimization methods. (3-0) R

MECH 6347 (EEMF 6382 and MSEN 6382) Introduction to MEMS (3 semester credit hours) Study of micro-electro-mechanical devices and systems and their applications. Microfabrication techniques and other emerging fabrication processes for MEMS are studied along with their process physics. Principles of operations of various MEMS devices such as mechanical, optical, thermal, magnetic, chemical/biological sensors/actuators are studied. Topics include: bulk/surface micromachining, LIGA, microsensors and microactuators in multiphysics domain. (3-0) T

MECH 6348 (EEMF 6322 and MSEN 6322) Semiconductor Processing Technology (3 semester credit hours) Modern techniques for the manufacture of semiconductor devices and circuits. Techniques for both silicon and compound semiconductor processing are studied as well as an introduction to the design of experiments. Topics include: wafer growth, oxidation, diffusion, ion implantation, lithography, etch and deposition. (3-0) T

MECH 6350 Advanced Solid Mechanics (3 semester credit hours) This course provides a foundation for studying mechanical behavior of materials analyzing deformation and failure problems common in engineering design and materials science. Topics to be covered include elasticity, elastic stability, wave propagation, plasticity, and fracture. This course explores static and dynamic stress analysis, two- and three-dimensional theory of stressed elastic solids, analyses of structural elements with applications in a variety of fields, variational theorems, and approximate solutions. Prerequisite: MECH 2320 or equivalent. (3-0) Y

MECH 6351 Finite Element Techniques I (3 semester credit hours) This course will provide an overview on the basic theory of the finite element methods (FEM) and application of FEM analysis in solid mechanics. Course topics include 1D elements and computational procedures, variational principles and Rayleigh-Ritz method, Galerkin finite element method, numerical discretization, imposition of constraints, 2D elements and basic programing steps, finite element solution techniques, application of FEM for vibration analysis, and use of commercial FEM codes. Prerequisite: MECH 2320 or equivalent. (3-0) Y

MECH 6353 Computational Mechanics (3 semester credit hours) This course provides an in-depth discussion on Finite Element Method (FEMs) for solving solid mechanics problems. The course topics include total and updated Lagrangian formulations in finite element methods, variational principles in continuum mechanics, FEM/meshfree shape functions and numerical discretization, adaptivity and error estimates, explicit and implicit time integration methods, stability and convergence analysis, space-time FEM formulation, Newton's method and constraints, method of line-search and arc-length methods, impact and contact, computational elasticity and inelasticity. Prerequisites: MECH 6351 or equivalent. (3-0) T

MECH 6354 Experimental Mechanics (3 semester credit hours) This course provides experimental techniques and theoretical analysis for measurements of deformations and analysis of stress in engineering materials and natural bio-materials subjected to mechanical loadings. Various methods for measurement and characterization of mechanical properties such as elastic modulus, strength, failure strain, toughness, etc. will be discussed. Essential theoretical modeling for analysis of experimental results will be presented. Experimental techniques such as scanning probe microscopy, nanoindentation, and micro-tensile testing, etc. will be introduced through several lab sessions. Prerequisite: MECH 3351 or equivalent. (3-0) Y

MECH 6355 Viscoelasticity (3 semester credit hours) This course provides an overview of advanced stress analysis of solids with properties strongly influenced by time, temperature, pressure, and humidity. Topics covered include: the material characterization and thermodynamic foundation of the constitutive behavior of time-dependent materials such as polymers, and composites; time-temperature superposition principle for thermorheologically simple materials; correspondence principle; integral formulation for quasi-static boundary value problems; treatment of time-varying boundary conditions; linear viscoelastic stress waves, approximate methods of linear viscoelastic stress analysis; and introduction to nonlinear viscoelastic constitutive laws. Prerequisite: MECH 6306 or MECH 6350 or equivalent. (3-0) R

MECH 6356 Fracture Mechanics (3 semester credit hours) This course provides an introduction to analytical and experimental techniques for material failure by crack initiation and growth. Topics include fracture mechanics of brittle and ductile materials, asymptotic stress field in elastic and elastic-plastic materials, fracture criteria, fracture by cleavage, void growth, cohesive zone models, crack deflection, time-dependent fracture, dynamic fracture, and fatigue crack growth and life prediction. Prerequisite: MECH 6306 or MECH 6350. (3-0) T

MECH 6357 (MSEN 6380) Phase Transformations and Kinetic Processes in Materials (3 semester credit hours) This course covers diffusion, interfacial motion, nucleation, precipitation, order-disorder transitions, phase transformations, and dynamical processes at grain boundaries and on surfaces. Both macroscopic and atomic-scale approaches are used to understand these phenomena. Particular applications considered include phase transformations in bulk materials, surface evolution and thin-film growth, semiconductor processing, and nanomaterials synthesis. Prerequisites: (MECH 5300 and MSEN 5310) or equivalents. (3-0) T

MECH 6358 (MSEN 6381) Advanced Ceramic Materials (3 semester credit hours) This course covers fundamental material properties and modern applications of ceramic materials. The mechanical, optical, electronic and chemical properties of advanced ceramic materials are related to atomic structures and defects. Both conventional engineering ceramics and emerging applications of ceramics in nanotechnology, medical devices, and clean energy are reviewed. Advanced experimental and theoretical approaches in ceramics research are also discussed. Prerequisites: (MECH 5300 and MSEN 5310) or equivalents. (3-0) T

MECH 6359 (MSEN 6383) Modern Physical Metallurgy (3 semester credit hours) This course provides a basic understanding of the underlying principles that determine microstructural evolution in bulk materials and thin films during processing, and how microstructure determines their properties & performance in service. The course covers fundamental crystallography, including atomistic crystal structures and defect structures; thermodynamics and phase diagrams; kinetics of phase transformations; alloy and micro-structural engineering; and structure-property relationships that determine mechanical and electrical performance. Additionally, metallization and the reliability of multilevel interconnection and packaging for semiconductor and electronic devices are discussed. Prerequisites: (MECH 5300 and MSEN 5310) or equivalents. (3-0) R

MECH 6367 (MSEN 6310) Mechanical Properties of Materials (3 semester credit hours) Phenomenology of mechanical behavior of materials at the macroscopic level and the relationship of mechanical behavior to material structure and mechanisms of deformation and failure. Topics covered include elasticity, viscoelasticity, plasticity, creep, fracture, and fatigue. Prerequisite: MECH 2320 or MECH 5300 or equivalent. (3-0) R

MECH 6368 Imperfections in Crystalline Solids (3 semester credit hours) Basic quantitative understanding in the behavior of point, line, and planar defects in crystalline solids. Particular attention is focused on those defects that control the thermodynamic, structural, and mechanical properties of crystalline materials. Prerequisite: MECH 6306 or MECH 6350 or equivalent. (3-0) R

MECH 6370 Incompressible Fluid Mechanics (3 semester credit hours) Fundamentals of fluid mechanics of Newtonian, incompressible flows in various regimes. Derivation of governing equations of motion, and introduction to viscous internal and external flows in laminar and turbulent regimes. Prerequisite: MECH 3315 or equivalent. (3-0) Y

MECH 6371 Computational Thermal Fluid Science (3 semester credit hours) This course presents computational methods for viscous flow, boundary layer theory, and turbulence. Formulation of finite element methods and other traditional numerical techniques for analysis of dynamic problems in fluid mechanics will be examined. Prerequisite: MECH 6370 or equivalent. (3-0) Y

MECH 6372 Turbulent Flows (3 semester credit hours) In the first part of the course the governing equations will be reviewed. The vorticity equation will be derived giving emphasis to the vortex stretching and vortex tilting. Classical flows such as wall bounded flows, jets, mixing layers will be reviewed and the stability of the flow and transition from laminar to turbulence will be discussed. The spectrum of turbulence kinetic energy and the budget of kinetic energy will be illustrated. The course will also cover numerical methods to simulate turbulence, including Direct Numerical Simulations (DNS), Large Eddy Simulations (LES), and Reynolds-Average Navier-Stokes (RANS) equations and models. (3-0) R

MECH 6373 Convective Heat Transfer (3 semester credit hours) The course begins by reviewing the equations of motion of viscous fluids. Energy equation that governs the heat transfer across a fluid layer is introduced. Discussion of exact and approximate solutions of forced and free convection is an integral part of the course. Laminar and turbulent flow regimes will be covered with discussions of turbulent transport and modeling. (3-0) Y

MECH 6374 Conductive and Radiative Heat Transfer (3 semester credit hours) Advanced conduction heat transfer followed by advanced radiation heat transfer. Emphasis on fundamental concepts of conduction/diffusion in heat and mass transfer including solving differential equations related to conduction. Radiation heat transfer covering black and non-black surfaces, shape factors, radiation exchange in gray diffuse enclosures, and solution methods for integro-differential equations. Multi-mode heat transfer combining conduction and radiation is also covered. (3-0) R

MECH 6375 Phase Change Heat Transfer (3 semester credit hours) Introduction to the physics and significant progresses in phase change heat transfer and two-phase flow. Boiling, evaporation and condensation heat transfer will be followed by the study of external and internal two-phase flow. Boiling includes incipience phenomena, nucleate and film boiling regimes, and critical heat flux in pool and flow boiling. Condensation includes filmwise and dropwise condensation. Selected application topics related to phase change thermal transport will also be covered. (3-0) R

MECH 6376 Experimental Thermal and Fluid Dynamics (3 semester credit hours) This course presents an introduction to experiments in thermo-fluid dynamics. Similarity theory and basic concepts to perform experiments are discussed. A description of different types of wind tunnels is given, with emphasis on the design process of a general-purpose subsonic wind tunnel. A review of the most common measurement techniques is provided, such as for fluid pressure, forces, velocity, temperature, and density. The second part of the course focuses on signal processing through statistical, spectral analysis, and modal decomposition techniques. The final part of the course is devoted to the design and execution of an experiment. (3-0) R

MECH 6377 Advanced Thermodynamics (3 semester credit hours) This course provides a more advanced study of engineering thermodynamics. It includes an examination of the fundamental concepts of classical, macroscopic thermodynamics at a level beyond what is covered in a first course. The course coverage includes additional advanced topics such as exergy, thermodynamic property relationships, gas mixtures, gas-vapor mixture properties, chemical reactions, and thermodynamics of advanced energy systems. A brief introduction to the microscopic aspects of thermodynamics will provide a foundation for understanding the principles of statistical thermodynamics. (3-0) R

MECH 6378 Introduction to Compressible Fluid Mechanics (3 semester credit hours) Introduction to the theory of compressible fluid flow. Coverage of fundamental concepts such as wave propagation in compressible media, speed of sound, Mach number, and thermodynamic relationships. This course focuses on steady, one-dimensional compressible flows and the effects of variable area, friction, and heat transfer. Normal shockwaves and the use of nozzles and diffusers are reviewed. The engineering applications of compressible flows. A brief introduction to more advanced topics such as oblique shocks will also be provided. Prerequisites: MECH 3320 and MECH 3351 and MECH 4310. (3-0) R

MECH 6383 (EEMF 6383 and PHYS 6383) Plasma Science (3 semester credit hours) Theoretically oriented study of plasmas. Topics to include: fundamental properties of plasmas, fundamental equations (kinetic and fluid theory, electromagnetic waves, plasma waves, plasma sheaths), plasma chemistry and plasma diagnostics. Prerequisite: EEGR 6316 or equivalent. (3-0) T

MECH 6391 (EEGR 6381) Computational Methods in Engineering (3 semester credit hours) Numerical techniques and their applications in engineering. Topics will include: numerical methods of linear algebra, interpolation, solution of nonlinear equations, numerical integration, Monte Carlo methods, numerical solution of ordinary and partial differential equations, and numerical solution of integral equations. Prerequisites: ENGR 2300 and ENGR 3300 or equivalent, and knowledge of a scientific programming language. (3-0) R

MECH 6V29 Special Topics in Dynamic Systems and Control (1-6 semester credit hours) Selected advanced topics in controls and dynamic systems are covered in organized lectures. May be repeated for credit as topics vary. Additional prerequisites may be required depending on the specific course topic. (9 semester credit hours maximum). ([1-6]-0) R

MECH 6V49 Special Topics in Manufacturing and Design Innovation (1-6 semester credit hours) Selected advanced topics in manufacturing and design innovation are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). Additional prerequisites may be required depending on the specific course topic. ([1-6]-0) R

MECH 6V69 Special Topics in Mechanics and Materials (1-6 semester credit hours) Selected topics in mechanics and materials are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). Additional prerequisites may be required depending on the specific course topic. ([1-6]-0) R

MECH 6V89 Special Topics in Thermal and Fluid Sciences (1-6 semester credit hours) Selected advanced topics in thermal and fluid sciences are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). Additional prerequisites may be required depending on the specific course topic. ([1-6]-0) R

MECH 6V95 Topics in Mechanical Engineering (1-9 semester credit hours) Selected topics in mechanical engineering are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-9]-0) R

MECH 6V96 Individual Instruction in Mechanical Engineering (1-6 semester credit hours) Selected advanced topics in mechanical engineering. For letter grade credit only. May be repeated for credit (18 semester credit hours maximum). Instructor consent required. ([1-6]-0) R

MECH 6V97 Research in Mechanical Engineering (1-9 semester credit hours) A research project on a topic in mechanical engineering is conducted under supervision of a faculty advisor. Pass/Fail only. May be repeated for credit (18 semester credit hours maximum). Instructor consent required. ([1-9]-0) S

MECH 6V98 Thesis (3-9 semester credit hours) A research project on a topic in mechanical engineering is conducted under supervision of a supervisory committee. Research findings are documented in thesis. Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

MECH 7100 Seminar in Mechanical Engineering (1 semester credit hour) This course presents mechanical engineering graduate students with a wide spectrum of topics of interest to broaden knowledge beyond their specific areas of research and studies. Seminars will cover all concentration areas of research within mechanical engineering, including thermal and fluid sciences; dynamical systems and control; manufacturing and design innovation; and mechanics and materials. Pass/Fail only. May be repeated for credit as topics vary (9 semester credit hours maximum). (1-0) S

MECH 7392 Advanced Mathematics for Mechanical Engineers I (3 semester credit hours) Linear algebra and matrix analysis, tensor analysis, multivariable calculus and analytic geometry, vector integral calculus, closed-form and numerical solutions of ordinary differential equations, and stability. Prerequisites: PhD students or department consent required. (3-0) R

MECH 7393 Advanced Mathematics for Mechanical Engineers II (3 semester credit hours) Special functions, complex functions, complex integrals, conformal mapping, Fourier series, Fourier and Laplace transforms, systems of nonlinear equations, closed form, and numerical solutions of partial differential equations. Prerequisites: PhD students or department consent required. (3-0) R

MECH 7V29 Advanced Special Topics in Dynamic Systems and Control (1-6 semester credit hours) Selected contemporary topics in dynamic systems and controls are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

MECH 7V49 Advanced Special Topics in Manufacturing and Design Innovation (1-6 semester credit hours) Selected contemporary topics in manufacturing and design innovation are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

MECH 7V69 Advanced Special Topics in Mechanics and Materials (1-6 semester credit hours) Selected contemporary topics in mechanics and materials are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

MECH 7V89 Advanced Special Topics in Thermal and Fluid Sciences (1-6 semester credit hours)

Selected contemporary topics in thermal and fluid sciences are covered in organized lectures. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

MECH 8V70 Advanced Research in Mechanical Engineering (1-9 semester credit hours) A research project on an advanced topic in mechanical engineering is conducted under supervision of a faculty advisor. Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

MECH 8V99 Dissertation (1-9 semester credit hours) A research project on an advance topic in mechanical engineering is conducted under the supervision of a supervisory committee. Research findings are documented in dissertation. Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

Materials Sciences and Engineering

MSEN 5300 (MECH 5300 and PHYS 5376) Introduction to Materials Science (3 semester credit hours) This course provides an extensive overview of materials science and engineering and includes the foundations required for further graduate study in the field. Topics include chemical bonding, crystalline structures, imperfections and diffusion in solids, mechanical properties, strengthening and failure mechanisms, phase diagrams and transformations, corrosion and degradation of materials, metal alloys, ceramics, polymers, composites, as well as their electrical, thermal, magnetic, and optical properties. Quantitative analyses will be emphasized. (3-0) R

MSEN 5310 Thermodynamics of Materials (3 semester credit hours) Work, energy and the first law of thermodynamics; the second law of thermodynamics, thermodynamic potentials, the third law of thermodynamics, thermodynamic identities and their uses, phase equilibria in one-component systems, behavior and reactions of gases. Solutions, binary and multicomponent systems: phase equilibria, materials separation and purification. Electrochemistry. Thermodynamics of modern materials. (3-0) S

MSEN 5320 Materials Science for Sustainable Energy (3 semester credit hours) Sustainable energy solutions require examining current fossil fuel supply, climate change, and renewable energy source development. Fossil fuel supply and climate change are intimately related, and the global community is actively developing renewable energy source to replace the fossil fuel and minimize its impact on the climate change. Materials science will enable diverse renewable energy technologies (solar cell, biofuel, wind, geothermal etc.) and their practical utilization (energy storage, fuel cell, electrical vehicles, etc.). This course will examine energy and climate issues and sustainable energy solutions with emphasis on the role of materials science. (3-0) T

MSEN 5331 (CHEM 5331) Advanced Organic Chemistry I (3 semester credit hours) Modern concepts of bonding and structure in covalent compounds. Static and dynamic stereochemistry and methods for study. Relationships between structure and reactivity. Prerequisite: Undergraduate organic chemistry or instructor consent required. (3-0) Y

MSEN 5340 (CHEM 5340) Advanced Polymer Science and Engineering (3 semester credit hours) Polymer structure-property relations, Glass transition temperature and mechanical properties of polymers, Thermoplastics, thermosets, and elastomers, morphology of polymers, rheology of polymers, biodegradable and biocompatible polymers for drug delivery and tissue engineering applications. (3-0) R

MSEN 5341 (CHEM 5341) Advanced Inorganic Chemistry I (3 semester credit hours) Physical inorganic chemistry addressing topics in structure and bonding, symmetry, acids and bases, coordination chemistry and spectroscopy. Prerequisite: Undergraduate inorganic chemistry or instructor consent required. (3-0) Y

MSEN 5355 (CHEM 5355) Analytical Techniques I (3 semester credit hours) Study of fundamental analytical techniques, including optical spectroscopic techniques, mass spectrometry, and microscopic and surface analysis methods. (3-0) Y

MSEN 5360 Materials Characterization (3 semester credit hours) Survey of atomic and structural analysis techniques as applied to surface and bulk materials. Physical processes involved in the interaction of ions, electrons and photons with solids; characteristics of the emergent radiation in relation to the structure and composition. Prerequisite: MSEN 5300. Prerequisite or Corequisite: MSEN 6319 or equivalent. (3-0) S

MSEN 5361 Fundamentals of Surface and Thin Film Analysis (3 semester credit hours) Survey of materials characterization techniques; Rutherford backscattering; secondary ion mass spectroscopy; ion channeling; scanning tunneling and transmission microscopy; x-ray photoelectron and Auger electron spectroscopy; x-ray and electron diffraction. Prerequisite: MSEN 5360 or equivalent. (3-0) R

MSEN 5371 (PHYS 5371) Solid State Physics (3 semester credit hours) Symmetry description of crystals, bonding, properties of metals, electronic band theory, thermal properties, lattice vibration, elementary properties of semiconductors. Prerequisites: PHYS 5301 and PHYS 5320 or equivalent. (3-0) Y

MSEN 5377 (PHYS 5377) Computational Physics of Nanomaterials (3 semester credit hours) This course introduces atomistic and quantum simulation methods and their applications to modeling study nanomaterials (nanoparticles, nanowires, and thin films). The course has three main parts: basic theory of materials (thermodynamics, statistical mechanics, and solid state physics), computational methods to model materials systems, and applications to practical problems. There are three main themes of the course: structure-property relationship of nanomaterials; atomistic modeling for atomic structure optimization; and quantum simulations for electronic structure study and functional property analysis. Prerequisite: MSEN 6319 or equivalent. (3-0) R

MSEN 6310 (MECH 6367) Mechanical Properties of Materials (3 semester credit hours) Phenomenology of mechanical behavior of materials at the macroscopic level and the relationship of mechanical behavior to material structure and mechanisms of deformation and failure. Topics covered include elasticity, viscoelasticity, plasticity, creep, fracture, and fatigue. Prerequisite: MECH 2320 or MSEN 5300 or equivalent. (3-0) R

MSEN 6319 Quantum Mechanics for Materials Scientists (3 semester credit hours) Quantum-mechanical foundation for study of nanometer-scale materials. Principles of quantum physics, operators and Dirac notation, stationary-states for one-dimensional potentials, and the hydrogen atom. Introduction to: angular momentum and spin, chemical bonding and molecular orbital theory, and crystalline solids and band theory. (3-0) Y

MSEN 6320 (EEMF 6320) Fundamentals of Semiconductor Devices (3 semester credit hours) Semiconductor material properties, band structure, equilibrium carrier distributions, non-equilibrium current-transport processes, and recombination-generation processes. Corequisite: EEMF 6319 or equivalent. (3-0) Y

MSEN 6321 (EEMF 6321) Active Semiconductor Devices (3 semester credit hours) The physics of operation of active devices will be examined, including p-n junctions, bipolar junction transistors and field-effect transistors: MOSFETs, JFETS, and MESFETS. Active two-terminal devices and optoelectronic devices will be presented. Recommended corequisite: EEMF 6320 or MSEN 6320. (3-0) Y

MSEN 6322 (EEMF 6322 and MECH 6348) Semiconductor Processing Technology (3 semester credit hours) Modern techniques for the manufacture of semiconductor devices and circuits. Techniques for both silicon and compound semiconductor processing are studied as well as an introduction to the design of experiments. Topics include: wafer growth, oxidation, diffusion, ion implantation, lithography, etch and deposition. (3-0) T

MSEN 6323 Quantum Mechanics for Materials Scientists II (3 semester credit hours) Perturbation theory and approximation methods; scattering theory; elements of second quantization and many-body theory; exchange and spin statistics; interaction of radiation with matter; relativistic effects; band structure, and vibrational and optical properties of crystals; optionally, quantum information theory. Prerequisite: MSEN 6319 (or equivalent with permission of instructor.) (3-0) Y

MSEN 6324 (EEMF 6324) Electronic, Optical and Magnetic Materials (3 semester credit hours) Foundations of materials properties for electronic, optical and magnetic applications. Electrical and thermal conduction, elementary quantum physics, modern theory of solids, semiconductors and devices, dielectrics, magnetic and optical materials properties. Prerequisite: MSEN 5300 or equivalent. (3-0) T

MSEN 6325 Semiconductor Materials, Defects, and Devices (3 semester credit hours) This course provides the fundamental basis for understanding semiconductor electronic materials and devices. Starting from basic materials properties and electronic band structure, intrinsic and extrinsic semiconductors, the necessary derivation of carrier distributions, transport processes and equations, ac and dc response in junctions and capacitors, and the impact of bulk and interface defects are explored in traditional and novel nanoelectronic devices. Prerequisites: MSEN 5310 and MSEN 6319 and MSEN 6324. (3-0) Y

MSEN 6327 (EEMF 6327) Semiconductor Device Characterization (3 semester credit hours) This course will describe the theoretical and practical considerations associated with the most common electrical and reliability characterization techniques used in the semiconductor industry. Prerequisite: (EEMF 6320 or MSEN 6320 or MSEN 6325 or equivalent) or instructor consent required. (3-0) T

MSEN 6338 Advanced Theory of Semiconductors: Electronic Structure and Transport (3 semester credit hours) This course discusses: 1. The electronic structure of semiconductors and small semiconductor structures starting from basic condensed-matter theory; 2. The nature of elementary excitations (such as phonons, plasmons, interface and surface excitations, etc.) in terms of the many-body, second quantization language; 3. The interaction of electrons with these excitations, as well as photons; and, 4. The equations which govern electronic transport at the nanometer scale. Recommended prior coursework: one or more semesters of graduate quantum mechanics or equivalent. (3-0) T

MSEN 6339 Nanostructured Materials: Synthesis, Properties and Application (3 semester credit hours) Exploration of the synthesis, properties and applications of quantum dots, wells, rods, wires, particles and related nanostructures. The theoretical and experimental evidence for quantum-confinement effects, which are of considerable fundamental and applied interest, will be discussed. The manipulation of surface properties of nanostructures, their incorporation into bulk nanocomposites and their application to technological devices will be discussed. Prerequisites or Corequisites: MSEN 5310 and MSEN 5360 and MSEN 6319 and MSEN 6324, or equivalent. (3-0) T

MSEN 6340 Introduction to Electron Microscopy (3 semester credit hours) Theory and applications of scanning and transmission electron microscopy; sample preparation, ion beam and electron beam imaging techniques. Prerequisite: MSEN 5360 or equivalent. (2-1) Y

MSEN 6341 Advanced Electron Microscopy (3 semester credit hours) Theory and applications of advanced transmission electron microscopy; energy dispersive x-ray spectroscopy, electron energy loss spectroscopy and special techniques. Prerequisite: MSEN 6340. (2-1) Y

MSEN 6348 (EEMF 6348 and MECH 6341) Lithography and Nanofabrication (3 semester credit hours) Study of the principles, practical considerations, and instrumentation of major lithography technologies for nanofabrication of devices and materials. Advanced photolithography, electron beam lithography, nanoimprint lithography, x-ray lithography, ion beam lithography, soft lithography, and scanning probe lithography, basic resist and polymer science, applications in nanoelectronic and biomaterials. (3-0) Y

MSEN 6350 Imperfections in Solids (3 semester credit hours) Point defects in semiconductors, metals, ceramics, and nonideal defect structures; nonequilibrium conditions produced by irradiation or quenching; effects of defects on electrical and physical properties, effects of defects at interfaces between differing materials. Prerequisites: MSEN 5310 and MSEN 6324, or equivalent. (3-0) R

MSEN 6355 (BMEN 6355) Nanotechnology and Sensors (3 semester credit hours) Introduction to the concept of nanotechnology, in context toward designing sensors/diagnostic devices. Identifying the impact of nanotechnology in designing "state-of-the art" sensors for healthcare applications. Topics include: nanotechnology and nanomaterials, principles of sensing and transduction and heterogeneous integration toward sensor design. (3-0) Y

MSEN 6358 (BIOL 6358) Bionanotechnology (3 semester credit hours) Protein, nucleic acid and lipid structures. Macromolecules as structural and functional units of the intact cell. Parallels between biology and nanotechnology. Applications of nanotechnology to biological systems. (3-0) T

MSEN 6362 Diffraction Science (3 semester credit hours) Diffraction theory; scattering and diffraction experiments; kinematic theory; dynamical theory; x-ray topography; crystal structure analysis; disordered crystals; quasi-crystals. (3-0) R

MSEN 6371 (PHYS 6371) Advanced Solid State Physics (3 semester credit hours) Continuation of MSEN 5371 or PHYS 5371, transport properties of semiconductors, ferroelectricity and structural phase transitions, magnetism, superconductivity, quantum devices, surfaces. Prerequisite: MSEN 5371 or PHYS 5371 or equivalent. (3-0) R

MSEN 6374 (PHYS 6374) Optical Properties of Solids (3 semester credit hours) Optical response in solids and its applications. Lorentz, Drude and quantum mechanical models for dielectric response function. Kramers-Kronig transformation and sum rules considered. Basic properties related to band structure effects, excitons and other excitations. Experimental techniques including reflectance, absorption, modulated reflectance, Raman scattering. Prerequisite: MSEN 5371 or PHYS 5371 or equivalent. (3-0) R

MSEN 6377 (PHYS 6377) Physics of Nanostructures: Carbon Nanotubes, Fullerenes, Quantum Wells, Dots and Wires (3 semester credit hours) Electronic bands in low dimensions. 0-D systems: fullerenes and quantum dots. Optical properties, superconductivity and ferromagnetism of fullerides. 1-D systems: nano-wires and carbon nanotubes (CNTs). Energy bands of CNTs: chirality and electronic spectrum. Metallic versus semiconducting CNT: arm-chair, zigzag and chiral tubes. Electrical conductivity and superconductivity of CNTs, thermopower. Electromechanics of SWCNT: artificial muscles. Quantum wells, FETs and organic superlattices: confinement of electrons and excitons. Integer and fractional quantum Hall effect (QHE). (3-0) R

MSEN 6380 (MECH 6357) Phase Transformations and Kinetic processes in Materials (3 semester credit hours) This course covers diffusion, interfacial motion, nucleation, precipitation, order-disorder transitions, phase transformations, and dynamical processes at grain boundaries and on surfaces. Both macroscopic and atomic-scale approaches are used to understand these phenomena. Particular applications considered include phase transformations in bulk materials, surface evolution and thin-film growth, semiconductor processing, and nanomaterials synthesis. Prerequisites: (MSEN 5300 and MSEN 5310) or equivalents. (3-0) T

MSEN 6381 (MECH 6358) Advanced Ceramic Materials (3 semester credit hours) This course covers fundamental material properties and modern applications of ceramic materials. The mechanical, optical, electronic and chemical properties of advanced ceramic materials are related to atomic structures and defects. Both conventional engineering ceramics and emerging applications of ceramics in nanotechnology, medical devices, and clean energy are reviewed. Advanced experimental and theoretical approaches in ceramics research are also discussed. Prerequisites: (MSEN 5300 and MSEN 5310) or equivalents. (3-0) T

MSEN 6382 (EEMF 6382 and MECH 6347) Introduction to MEMS (3 semester credit hours) Study of micro-electro-mechanical devices and systems and their applications. Microfabrication techniques and other emerging fabrication processes for MEMS are studied along with their process physics.

Principles of operations of various MEMS devices such as mechanical, optical, thermal, magnetic, chemical/biological sensors/actuators are studied. Topics include: bulk/surface micromachining, LIGA, microsensors and microactuators in multiphysics domain. (3-0) T

MSEN 6383 (MECH 6359) Modern Physical Metallurgy (3 semester credit hours) This course provides a basic understanding of the underlying principles that determine microstructural evolution in bulk materials and thin films during processing, and how microstructure determines their properties and performance in service. The course covers fundamental crystallography, including atomistic crystal structures and defect structures; thermodynamics and phase diagrams; kinetics of phase transformations; alloy and micro-structural engineering; and structure-property relationships that determine mechanical and electrical performance. Additionally, metallization and the reliability of multilevel interconnection and packaging for semiconductor and electronic devices are discussed. Prerequisites: (MECH 5300 and MSEN 5310) or equivalents. (3-0) T

MSEN 6V98 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

MSEN 7V80 Special Topics in Materials Science and Engineering (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) S

MSEN 8V40 Individual Instruction in Materials Science and Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-6]-0) S

MSEN 8V70 Research in Materials Science and Engineering (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

MSEN 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

Software Engineering

SE 5354 Software Engineering (3 semester credit hours) Formal specification and program verification. Software life-cycle models and their stages. System and software requirements engineering; user-interface design. Software architecture, design, and analysis. Software testing, validation, and quality assurance. Prerequisite or Corequisite: CS 5343. (3-0) S

SE 5V81 Special Topics in Computer Science (1-9 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

SE 6301 Special Topics in Software Engineering (3 semester credit hours) May be repeated for credit as topics vary. Prerequisite: CS 5343. (3-0) S

SE 6316 Agile Methods (3 semester credit hours) The course addresses what agile methods are, how they are implemented (correctly), and their impact on software engineering. A variety of agile methods are described with a focus on Scrum. Issues associated with planning and controlling agile projects, along with the challenges associated with adopting agile methods are discussed. Prerequisite: SE 5354. (3-0) Y

SE 6329 Object-Oriented Software Engineering (3 semester credit hours) Concepts, methods and techniques necessary to efficiently capture software requirements in use cases and transform them into design and implementation. Use of UML in the context of an iterative, agile process with an OO model transformation approach. Use of an advanced CASE tool that allows the synchronization between the various models and the code. Prerequisites: SE 5354 and knowledge of Java. (3-0) S

SE 6354 Advanced Software Engineering (3 semester credit hours) This course covers advanced theoretical concepts in software engineering and provides an extensive hands-on experience in dealing with various issues of software development. It involves a semester-long group software development project spanning software project planning and management, analysis of requirements, construction of software architecture and design, implementation, and quality assessment. The course will introduce formal specification, component-based software engineering, and software maintenance and evolution. Must have knowledge of Java. Prerequisite: SE 5354 or equivalent. (3-0) S

SE 6356 (CS 6356 and SYSM 6308) Software Maintenance, Evolution, and Re-Engineering (3 semester credit hours) Principles and techniques of software maintenance. Impact of software development process on software justifiability, maintainability, evolvability, and planning of release cycles. Use of very high-level languages and dependencies for forward engineering and reverse engineering. Achievements, pitfalls, and trends in software reuse, reverse engineering, and re-engineering. Prerequisite: SE 5354. (3-0) Y

SE 6361 (CS 6361 and SYSM 6309) Advanced Requirements Engineering (3 semester credit hours) System and software requirements engineering. Identification, elicitation, modeling, analysis, specification, management, and evolution of functional and non-functional requirements. Strengths and weaknesses of different techniques, tools, and object-oriented methodologies. Interactions and trade-offs among hardware, software, and organization. System and sub-system integration with software and organization as components of complex, composite systems. Transition from requirements to design. Critical issues in requirements engineering. Prerequisite: SE 5354. (3-0) S

SE 6362 Advanced Software Architecture and Design (3 semester credit hours) Concepts and methodologies for the development, evolution, and reuse of software architecture and design, with an emphasis on object-orientation. Identification, analysis, and synthesis of system data, process, communication, and control components. Decomposition, assignment, and composition of functionality to design elements and connectors. Use of non-functional requirements for analyzing trade-offs and selecting among design alternatives. Transition from requirements to software architecture, design, and to implementation. State of the practice and art. Prerequisite: SE 5354. (3-0) S

SE 6367 (CS 6367 and SYSM 6310) Software Testing, Validation and Verification (3 semester credit hours) Fundamental concepts of software testing. Functional testing. GUI based testing tools.

Control flow based test adequacy criteria. Data flow based test adequacy criteria. White box based testing tools. Mutation testing and testing tools. Relationship between test adequacy criteria. Finite state machine based testing. Static and dynamic program slicing for testing and debugging. Software reliability. Formal verification of program correctness. Prerequisite: SE 5354. (3-0) Y

SE 6387 Advanced Software Engineering Project (3 semester credit hours) This course is intended to provide experience in a group project that requires advanced technical solutions, such as distributed multi-tier architectures, component-based technologies, automated software engineering, etc., for developing applications, such as web-based systems, knowledge-based systems, real-time systems, etc. The students will develop and maintain requirements, architecture and detailed design, implementation, and testing and their traceability relationships. Best practices in software engineering will be applied. Prerequisites: (CS 6361 or SE 6361 or SYSM 6309) or SE 6362 and (SE 6329 or CS 6359). Corequisite: CS 6367 or SE 6367 or SYSM 6310. (3-0) Y

SE 6388 Software Project Planning and Management (3 semester credit hours) Techniques and disciplines for successful management of software projects. Project planning and contracts. Advanced cost estimation models. Risk management process and activities. Advanced scheduling techniques. Definition, management, and optimization of software engineering processes. Statistical process control. Software configuration management. Capability Maturity Model Integration (CMMI). Prerequisite: SE 5354. (3-0) Y

SE 6V81 Independent Study in Software Engineering (1-9 semester credit hours) May be repeated for credit. Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

SE 7301 (CS 7301) Recent Advances in Computing (3 semester credit hours) Advanced topics and publications will be selected from the theory, design, and implementation issues in computing. May be repeated for credit as topics vary. Prerequisites: ENCS majors only and instructor consent required. (3-0) Y

SE 8V02 Topics in Software Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary (9 semester credit hours maximum). Prerequisite: ENCS majors only and instructor consent required. ([1-6]-0) S

SE 8V07 Research (1-9 semester credit hours) Open to students with advanced standing subject to approval of the graduate advisor. Pass/Fail only. May be repeated for credit. Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

SE 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Prerequisites: ENCS majors only and instructor consent required. ([1-9]-0) S

Systems Engineering

SYSE 6322 (MECH 6316) Digital Control of Automotive Powertrain Systems (3 semester credit hours) Digital control systems, discretization and design by equivalents. Input-output design and discrete-time state variable estimation and control. Introduction to various control problems in automotive powertrains. Application of digital control principles to automotive powertrains for internal combustion engine idle speed control and air-to-fuel ratio control. Prerequisite: A basic course in control systems at the undergraduate level. (3-0) T

SYSE 6323 (EECS 6323 and MECH 6323) Robust Control Systems (3 semester credit hours) Theory, methodology, and software tools for the analysis and design of model-based control systems with multiple actuators and multiple sensors. Control oriented model parameterizations and modeling errors. Definitions and criteria for robust stability and performance. Optimal synthesis of linear controllers. The loop shaping design method. Methods to simplify the control law. Mechatronic design examples. Prerequisite: MECH 4310 or equivalent and MECH 6300 or EECS 6331 or SYSM 6307 or equivalent. (3-0) T

SYSE 6324 (BMEN 6388 and EECS 6336 and MECH 6313) Nonlinear Systems (3 semester credit hours) Equilibria, phase portraits, linearization of nonlinear systems; periodic solutions; Poincare-Bendixson theorem; fundamental existence and uniqueness theorem for ODEs; Lyapunov stability theory; Invariance principle and LaSalle's theorem; converse theorems; singular perturbations; center manifold theorem; differential geometric tools, feedback linearization, input-output linearization, output injection, output tracking, passivity-based control; backstepping. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307 or equivalent. (3-0) T

SYSE 6325 (MECH 6325) Optimal Estimation and Kalman Filter (3 semester credit hours) Theory, analysis, design, and implementation of Kalman filters are covered in this course together with real-world applications of the theory. Topics include a review of probability and random variables; random signals and random processes; response of linear systems to random signals; the Wiener filter; the discrete-time Kalman filter; continuous-time Kalman filter; prediction and smoothing; the extended Kalman filter; the ensemble Kalman filter; the unscented Kalman filter; case studies in GPS and GPS-aided inertial navigation, simultaneous localization and mapping (SLAM), and amplitude and phase estimation in dynamic mode atomic force microscopy (AFM). Prerequisite: MECH 6300 or SYSM 6307. (3-0) R

SYSE 6326 (BMEN 6324 and EECS 6324 and MECH 6324) Robot Control (3 semester credit hours) Dynamics of robots; methods of control; force control; robust and adaptive control; feedback linearization; Lyapunov design methods; passivity and network control; control of multiple and redundant robots; teleoperation. Prerequisite: EECS 6331 or MECH 6300 or SYSM 6307. (3-0) T

SYSE 6V60 Independent Study in Systems Engineering (1-9 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. ([1-9]-0) S

SYSE 6V70 Research in Systems Engineering (1-9 semester credit hours) Pass/Fail only. May be repeated for credit (9 semester credit hours maximum). Instructor consent required ([1-9]-0) R

SYSE 6V80 Special Topics (1-9 semester credit hours) This course focuses on special topics related to systems and control engineering typically not found in other courses. The course is generally open to all engineering students with graduate level standing particularly in electrical, mechanical, systems, computer science, and bioengineering. Department consent required. May be repeated for credit (9 semester credit hours maximum). ([1-9]-0) Y

SYSE 6V90 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit (9 semester credit hours maximum). Instructor Consent required ([3-9]-0) S

Systems Engineering and Management

SYSM 6009 Systems Engineering and Management Internship (0 semester credit hours) Student gains experience and improves skills through appropriate developmental work assignments in a real business environment. Student must identify and submit specific business learning objectives at the beginning of the semester. The student must demonstrate exposure to the managerial perspective via involvement or observation. At semester end, student prepares an oral or poster presentation, or a written paper reflecting on the work experience. Student performance is evaluated by the work supervisor. Pass/Fail only. Prerequisites: (MAS 6102 or MBA major) and department consent required. (0-0) S

SYSM 6301 (MECH 6337) Systems Engineering, Architecture and Design (3 semester credit hours) Architecture and design of large-scale and decentralized systems from technical and management perspectives. Systems architectures, requirements analysis, design tradeoffs, and reliability through various case studies and multiple types of mathematical techniques. International standardization bodies, including INCOSE, engineering frameworks, processes, and tool support from both theoretical and practical perspectives. (3-0) Y

SYSM 6302 (BMEN 6302 and EECS 6302 and MECH 6317) Dynamics of Complex Networks and Systems (3 semester credit hours) Design and analysis of complex interconnected networks and systems. Basic concepts in graph theory; Eulerian and Hamiltonian graphs; traveling salesman problems; random graphs; power laws; small world networks; clustering; introduction to dynamical systems; stability; chaos and fractals. (3-0) Y

SYSM 6303 (OPRE 6301) Statistics and Data Analysis (3 semester credit hours) Introduction to statistical and probabilistic methods and theory applicable to situations faced by managers. Topics include: data presentation and summarization, regression analysis, fundamental probability theory and random variables, introductory decision analysis, estimation, confidence intervals, hypothesis testing, and One Way ANOVA. Credit cannot be received for both: (OPRE 6301 or SYSM 6303) and (OPRE 6359 or BUAN 6359). (Some sections of this class may require a laptop computer). (3-0) S

SYSM 6304 (OPRE 6335) Risk and Decision Analysis (3 semester credit hours) This course provides an overview of the main concepts and methods of risk assessment, risk management, and decision analysis. The methods used in industry, such as probabilistic risk assessment, six sigma, and reliability, are discussed. Advanced methods from economics and finance (decision optimization and portfolio analysis) are presented. Prerequisite: OPRE 6301 or OPRE 6359 or BUAN 6359 or SYSM 6303. (3-0) T

SYSM 6305 Optimization Theory and Practice (3 semester credit hours) Basics of optimization theory, numerical algorithms, and applications. The course is divided into three main parts: linear programming (simplex method, duality theory), unconstrained methods (optimality conditions, descent algorithms and convergence theorems), and constrained minimization (Lagrange multipliers, Karush-Kuhn-Tucker conditions, active set, penalty and interior point methods). Applications in engineering, operations, finance, statistics, etc. will be emphasized. Students will also use Matlab's optimization toolbox to obtain practical experience with the material. (3-0) Y

SYSM 6306 (BMEN 6372 and MECH 6314) Engineering Systems: Modeling and Simulation (3 semester credit hours) This course will present principles of computational modeling and simulation of systems. General topics covered include: parametric and non-parametric modeling; system simulation; parameter estimation, linear regression and least squares; model structure and model validation through simulation; and, numerical issues in systems theory. Techniques covered include methods from numerical linear algebra, nonlinear programming and Monte Carlo simulation, with applications to general engineering systems. Modeling and simulation software is utilized (MATLAB/SIMULINK). (3-0) Y

SYSM 6307 (EECS 6331 and MECH 6300) Linear Systems (3 semester credit hours) State space methods of analysis and design for linear dynamical systems. Coordinate transformations and tools from advanced linear algebra. Controllability and observability. Lyapunov stability analysis. Pole assignment, stabilizability, detectability. State estimation for deterministic models, observers. Introduction to the optimal linear quadratic regulator problem. Prerequisites: ENGR 2300 and EE 4310 or MECH 4310 or equivalent. (3-0) Y

SYSM 6308 (CS 6356 and SE 6356) Software Maintenance, Evolution, and Re-Engineering (3 semester credit hours) Principles and techniques of software maintenance. Impact of software development process on software justifiability, maintainability, evolvability, and planning of release cycles. Use of very high-level languages and dependencies for forward engineering and reverse engineering. Achievements, pitfalls, and trends in software reuse, reverse engineering, and re-engineering. Prerequisite: SE 5354. (3-0) Y

SYSM 6309 (CS 6361 and SE 6361) Advanced Requirements Engineering (3 semester credit hours) System and software requirements engineering. Identification, elicitation, modeling, analysis, specification, management, and evolution of functional and non-functional requirements. Strengths and weaknesses of different techniques, tools, and object-oriented methodologies. Interactions and trade-offs among hardware, software, and organization. System and sub-system integration with software and organization as components of complex, composite systems. Transition from requirements to design. Critical issues in requirements engineering. Prerequisite: SE 5354. (3-0) S

SYSM 6310 (CS 6367 and SE 6367) Software Testing, Validation and Verification (3 semester credit hours) Fundamental concepts of software testing. Functional testing. GUI based testing tools. Control flow based test adequacy criteria. Data flow based test adequacy criteria. White box based testing tools. Mutation testing and testing tools. Relationship between test adequacy criteria. Finite state machine based testing. Static and dynamic program slicing for testing and debugging. Software reliability. Formal verification of program correctness. Prerequisite: SE 5354. (3-0) Y

SYSM 6311 (ENGY 6362 and IMS 6362 and OPRE 6362) Systems Project Management in Engineering and Operations (3 semester credit hours) Project management is the discipline of planning, organizing and managing resources to bring about the successful completion of specific project goals and objectives. The course will cover various aspects of managing projects in engineering and operations environments including the critical path methods for planning and controlling projects, time and cost tradeoffs, resource utilization, organizational design, conflict resolution and stochastic considerations. (3-0) S

SYSM 6312 (FIN 6301) Systems Financial Management (3 semester credit hours) Develops the basic concepts of finance with particular attention to their application to the financial management of companies. Prerequisites or Corequisites: (ACCT 6301 or ACCT 6305 or ACCT 6330 or HMGT 6311) and (BUAN 6359 or OPRE 6359 or OPRE 6301). (3-0) S

SYSM 6313 (HMGT 6324 and MECO 6352 and OB 6332) Systems Negotiation and Dispute Resolution (3 semester credit hours) This course explores the theories, processes, and practical techniques of negotiation so that students can successfully negotiate and resolve disputes in a variety of situations including interpersonal, group, and international settings. Emphasis is placed on understanding influence and conflict resolution strategies; identifying interests, issues, and positions of the parties involved; analyzing co-negotiators, their negotiation styles, and the negotiation situations; and managing the dynamics associated with most negotiations. Practical skills are developed through the use of simulations and exercises. (3-0) Y

SYSM 6315 (ENTP 6398) The Entrepreneurial Experience (3 semester credit hours) This course is designed to provide student teams with practical experience in the investigation, evaluation and recommendation of technology and/or market entry strategies for a significant new business opportunity. Projects will be defined by the faculty and will generally focus on emerging market opportunities defined by new technologies of interest to a sponsoring corporate partner. Teams will be comprised of management and engineering graduate students, mentored by faculty and representatives of the partnering company. Evaluation will be based on papers, presentations and other deliverables defined on a case-by-case basis. (3-0) R

SYSM 6316 (ENTP 6388) Managing Innovation within the Corporation (3 semester credit hours) Innovators and entrepreneurs within established corporations combine innovation, creativity and leadership to develop and launch new products, new product lines and new business units that grow revenues and profits from within. The course seeks to equip students with the skills and perspectives required to initiate new ventures and create viable businesses in dynamic and uncertain environments in the face of organizational inertia and other sources of resistance to innovation. Course topics include the elements of strategic analysis and positioning for competitive advantage in dynamic markets, and the structuring, utilization and mobilization of the internal resources of existing firms in the pursuit of growth and new market opportunities. (3-0) Y

SYSM 6318 (MKT 6301) Marketing Management (3 semester credit hours) This course provides an overview of marketing management methods, principles, and concepts, including product, pricing, promotion, and distribution decisions. Analytical techniques and tools such as segmentation, targeting, and positioning are introduced as key components of a more rigorous management science approach to marketing. The learning objective is to have students apply these methods, principles, and concepts to develop, evaluate, and implement effective strategic and tactical decisions in marketing. (3-0) S

SYSM 6319 (MECO 6303) Business Economics (3 semester credit hours) Foundations of the economic analysis of business problems, with special emphasis on the operation of markets and the macroeconomy. Prerequisite: OPRE 6303 or equivalent. (3-0) S

SYSM 6320 (BPS 6332) Strategic Leadership (3 semester credit hours) Addresses the challenge of leading organizations in dynamic and challenging environments. Overall goal is to not only question one's assumptions about leadership, but also enhance skills and acquire new content knowledge. Topics include visionary and transformational leadership, post-heroic leadership, empowerment, leveraging and combining resources, designing organizations and ethics. (3-0) Y

SYSM 6321 Financial Engineering (3 semester credit hours) Introduction to finance and investments from an engineering perspective. Focuses on the principles underlying financial decision making which are applicable to all forms of investment: stocks, bonds, real estate, project budgeting, corporate finance, and more. Intended for students with strong technical backgrounds who are comfortable with mathematical arguments. Primary components are deterministic finance (interest rates, bonds, and simple cash flow analysis) and single period uncertainty finance (portfolios of stocks and pricing theory). Prerequisites: Courses in engineering calculus, probability and linear algebra. (3-0) Y

SYSM 6325 Requirements Design, Development, and Integration for Complex Systems (3 semester credit hours) Building on the premise that systems engineering is the glue that holds complex programs together, this course will teach the foundations of effective requirements design and development for complex systems. Students will learn principles and techniques used for effective creation of requirements early within a system's lifecycle; including effective system integration planning. Practical skills are developed through the use of various case studies, and a significant group project (for real, "external" customers, when possible). Prerequisite or Corequisite: SYSM 6301. (3-0) Y

SYSM 6326 Systems Lifecycle Cost Analysis (3 semester credit hours) This course will provide an understanding of system lifecycle cost analysis concepts (also known as systems affordability) and the lifecycle costing process. The course will examine the importance of using these concepts when attempting to make the best possible engineering and business decisions throughout a system's lifecycle. The concepts will include special emphasis on the analysis and evaluation of alternatives by collectively weighing costs, risks and opportunities, performance, weight and other benefit/risk parameters. Topics will include total ownership cost, various estimating methods and techniques (including sensitivity and some risk analysis), cost analysis processes, system trade studies, and system cost effectiveness, to name a few. Practical skills are developed through the use of various case studies, and a significant group project, maturing from "concept" into "operations and support" throughout the semester. Prerequisite: SYSM 6301. (3-0) Y

SYSM 6327 Systems Reliability (3 semester credit hours) This course will provide an advanced understanding of reliability analysis of complex systems, including many of its extended analysis focus areas like availability, maintainability, and supportability (RAMS). Course analysis variables include stress under various conditions, the use of degradation data, relationships between accelerated stresses and normal operating conditions, dependency failures, repairable and non-repairable components, preventive maintenance, replacement and inspection, and accelerated life reliability models, to name a few. The course will also address important reliability metrics, and the impact of reliability in the design, development and management of organizations. Prerequisite: SYSM 6303 or OPRE 6301. (3-0) Y

SYSM 6328 Computer and Networks Systems Security (3 semester credit hours) This course is a comprehensive study of security principles and practices for computer and network systems. Topics to be covered include fundamental concepts in computer and network security and common attacks and attacking techniques on computer systems and networks. Practical security policies, defense strategies, and mechanisms, as well as fundamentals of cryptographic tools will be discussed. Defense techniques such as secured protocols, authentication, access control, and network intrusion detection will also be covered. Hands-on computer and network security labs using virtual machines will be used to enhance students' learning. Prerequisite: An undergraduate course on operating systems (e.g. CS 4348 or SE 4348) and instructor consent required. (3-0) Y

SYSM 6332 (ENTP 6375 and MIS 6375 and OPRE 6394) Technology and New Product Development (3 semester credit hours) This course addresses the strategic and organizational issues confronted by firms in technology-intensive environments. The course reflects six broad themes: (1) managing firms in technology-intensive industries; (2) forecasting key industry and technology trends; (3) linking technology and business strategies; (4) using technology as a source of competitive advantage; (5) organizing firms to achieve these goals; and (6) implementing new technologies in organizations. Students analyze actual situations in organizations and summarize their findings and recommendations in an in-depth term paper. The course also introduces concepts related to agile engineering. Case studies and class participation are stressed. (3-0) Y

SYSM 6333 (OB 6301) Systems Organizational Behavior (3 semester credit hours) The study of human behavior in organizations. Emphasizes theoretical concepts and practical methods for understanding, analyzing, and predicting individual, group, and organizational behavior. Topics include work motivation, group dynamics, decision making, conflict and negotiation, leadership, power, and organizational culture. Ethical and international considerations are also addressed. (3-0) S

SYSM 6334 (OPRE 6302) Systems Operations Management (3 semester credit hours) Operations Management integrates all of the activities and processes that are necessary to provide products and services. This course overviews methods and models that help managers make better operating decisions over time. How these methods will allow firms to operate both manufacturing and service facilities in order to compete in a global environment will also be discussed. Prerequisite or Corequisite: OPRE 6301 or BUAN 6359 or OPRE 6359. (3-0) S

SYSM 6335 (BUAN 6335) Organizing for Business Analytics Platforms (3 semester credit hours) The course develops conceptual understanding of platforms for business analytics and key business drivers that lead to business initiatives. The course examines how decision-makers in key functional areas of an enterprise rely on business analytics, how teams identify and develop analytical techniques to solve business problems, and how analytics platforms are adopted successfully. The course also emphasizes the development of business cases for strategic analytics initiatives and discusses best practices for descriptive, predictive, and prescriptive analytics. (3-0) T

SYSM 6337 (ACCT 6305) Accounting for Managers (3 semester credit hours) Fundamental concepts in accounting and financial reporting are presented from the perspective of business managers. May not be used to fulfill degree requirements in MS Accounting. Credit cannot be received for both courses, (ACCT 6301 or ACCT 6202) and ACCT 6305. (3-0) S

SYSM 6V70 Research In Systems Engineering and Management (1-9 semester credit hours) Pass/Fail only. May be repeated for credit (15 semester credit hours maximum). Instructor consent required. ([1-9]-0) R

SYSM 6V80 Special Topics in Systems Engineering and Management (1-6 semester credit hours) May be repeated as topics vary (9 semester credit hours maximum). ([1-6]-0) S

SYSM 6V90 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit (15 semester credit hours maximum). Instructor consent required. ([3-9]-0) S

SYSM 6V98 Systems Engineering and Management Internship (1-3 semester credit hours) Student gains experience and improves skills through appropriate developmental work assignments in a real business environment. Student must identify and submit specific business learning objectives at the beginning of the semester. The student must demonstrate exposure to the managerial perspective via involvement or observation. At semester end, student prepares an oral or poster presentation, or a written paper reflecting on the work experience. Student performance is evaluated by the work supervisor. Pass/Fail only. May be repeated for credit as topics vary (3 semester credit hours maximum). SEM Program Director, the School of Engineering Internship Coordinator, and department consent required. Prerequisite: MAS 6102 or MBA major. ([1-3]-0) S

Telecommunications Engineering

TE 6385 (CS 6385) Algorithmic Aspects of Telecommunication Networks (3 semester credit hours) This is an advanced course on topics related to the design, analysis, and development of telecommunications systems and networks. The focus is on the efficient algorithmic solutions for key problems in modern telecommunications networks, in centralized and distributed models. Topics include: main concepts in the design of distributed algorithms in synchronous and asynchronous models, analysis techniques for distributed algorithms, centralized and distributed solutions for handling design and optimization problems concerning network topology, architecture, routing, survivability, reliability, congestion, dimensioning and traffic management in modern telecommunication networks. Prerequisites: CS 5343 and CS 5348 and (CS 3341 or ENGR 3341 or equivalent). (3-0) Y

TE 6V98 Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

TE 8V40 Individual Instruction in Telecommunications Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-6]-0) S

TE 8V70 Research in Telecommunications Engineering (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

TE 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S