ECE MS Program in Electrical and Computer Engineering
Fall 2020 Course Offerings

ENG EC500-A1 Principles of Software At Scale **Prof. Trachtenberg**

Scaling software to many developers, modules, or machines requires a fundamentally different skillset from writing short prototype code. Software engineers working on large-scale web, financial and healthcare systems, or even multiplayer gaming must synthesize a wide variety elements at all abstraction layers, ranging from hardware and operating system constraints through considerations of distributed execution, security, databases, and front-end development.

This course will focus on the *principles* of scalable software engineering, including:

•**Design** – how to design code for efficiency, modularity, interoperability, security, and extensibility

•**Distribution** – the issues inherent in efficient and reliability distributed processing over many machines

•**Optimization** – the effects of design and distribution on performance, how optimization down to the hardware

•**Security –** fundamental elements of secure software design and implementation

The course will include significant amounts of programming, primarily in C++ and Java, but possibly in some higher-level languages as well. Students will be expected to learn language elements and software tools as needed, on the fly, and to collaborate in increasingly complex and collaborative programming projects. A fundamental background in software programming is thus mandatory, although a background in data structures or algorithms may also be helpful (but not required).
For additional information, click here.

ENG EC500-A2 Robot Learning and Vision for Navigation **Prof. Ohn-Bar**

In this class we will focus on one of society's most important problems: mobility. The task of autonomous navigation in complex and dynamic 3D environments is a fundamental (and urgent) engineering problem. There is a wide range of applications, from assistive systems to self-driving cars. Despite decades of research, existing perception, decision-making, and interaction algorithms for navigation perform poorly when compared to strategies employed by humans. The goal of this class is to provide theoretical and experimental frameworks for understanding such limitations while exploring novel solutions. We will use simulation environments and real-world datasets to analyze key questions, such as paradigms for the coupling of perception and control.

Topics discussed will include: sensorimotor learning using reinforcement, apprenticeship (imitation, inverse RL), self-supervised and evolutionary techniques, world representation and 3D vision, transportation systems.

ENG EC 501-A1 Dynamic System Theory **Prof. Baillieul**

Prereq: Familiarity with differential equations and matrices at the level of ENG EC 404 or CAS MA 242, or consent of instructor. Introduction to analytical concepts and examples of dynamic systems and control. Mathematical description and state space formation of dynamic systems; modeling, controllability, and observability. Eigenvector and transform analysis of linear systems including

canonical forms. Performance specifications. State feedback: pole placement and the linear quadratic regulator. Introduction to MIMO design and system identification using computer tools and laboratory experiments. Same as ENG ME 501 and ENG SE 501. Students may not receive credit for both. 4 cr.
Students registering for ENG 503 must register for a lecture section and a discussion section.

ENG EC 503-A1 Introduction to Learning from Data **Prof. Ishwar**
Prereq: (ENGEK381) This is an introductory course in statistical learning covering the basic theory, algorithms, and applications. This course will focus on the following major classes of supervised and unsupervised learning problems: classification, regression, density estimation, clustering, and dimensionality reduction. Generative and discriminative data models and associated learning algorithms of parametric and non-parametric varieties will be studied within both frequentist and Bayesian settings in a unified way. A variety of contemporary applications will be explored through homework assignments and a project. 4 cr.

ENG EC 504-A1 Advanced Data Structures **Prof. Brower**
Prereq: (ENGEC330) Review of basic data structures and Java syntax. Data abstraction and object-oriented design in the context of high-level languages and databases. Design implementation from the perspective of data structure efficiency and distributed control. Tailoring priority queues, balanced search trees, and graph algorithms to real-world problems, such as network routing, database management, and transaction processing.4 cr.

ENG EC 505-A1 Stochastic Processes **Prof. Saligrama**
Prereq: (ENGEC401 & CASMA142) or equivalent and either ENGEK381 or ENGEK500. Introduction to discrete and continuous-time random processes. Correlation and power spectral density functions. Linear systems driven by random processes. Optimum detection and estimation. Bayesian, Weiner, and Kalman filtering. 4 cr..

ENG EC 513-A1 Computer Architecture **Prof. Joshi**
Prereq: (ENGEC413 OR ENGEC605) Or instructor consent Grad Prereq: (ENGEC413 & ENGEC605) Or instructor consent. Computer architecture and design. Topics include computer arithmetic and ALU design; performance evaluation; instruction set design; CPU design, including pipelining, branch prediction, and speculative execution; memory hierarchy, including cache basics, cache design for performance, and virtual memory support; I/O, including devices, interfaces, specification, and modeling. Examples from high-end microprocessors and embedded systems. 4 cr.

ENG EC 516-A1 Digital Signal Processing **Prof. Nawab**
Prereq: (ENGEC401) And ENGEC381 or ENGEK381 Advanced structures and techniques for digital signal processing and their properties in relation to application requirements such as real-time, low-bandwidth, and low-power operation. Optimal FIR filter design; time-dependent Fourier transform and filterbanks; Hilbert transform relations; cepstral analysis and deconvolution; parametric signal modeling; multidimensional signal processing; multirate signal processing. 4 cr.

ENG EC 521-A1 Cybersecurity **Prof. Stringhini**
Prereq: (ENGEC327) Coreq: (ENGEC441) Fundamentals of security related to computers and computer networks. Laws and ethics. Social engineering and psychology-based attacks. Information gathering, network mapping, service enumeration, and vulnerability scanning. Operating system security related to access control, exploits, and disk forensics. Shellcoding. Wired and wireless network security at the

physical, network, and application layers. Theoretical lessons are augmented with case studies and demonstrative experimental labs. 4 cr.

ENG EC 523-A1 Deep Learning **Prof. Kulis**

Mathematical and machine learning background for deep learning. Feed-forward networks., Backpropagation. Training strategies for deep networks. Convolutional networks. Recurrent neural networks. Deep reinforcement learning. Deep unsupervised learning. Exposure to Tensorflow and other modern programming tools. Other recent topics, time permitting. 4 cr.

ENG EC 524-A1 Optimization Theory and Methods **Prof. Paschalidis**

Prereq:(ENGEK102 OR CASMA142 OR ENGEK103) *Introduction to optimization problems and algorithms emphasizing problem formulation, basic methodologies, and underlying mathematical structures. Classical optimization theory as well as recent advances in the field. Topics include modeling issues and formulations, simplex method, duality theory, sensitivity analysis, large-scale optimization, integer programming, interior-point methods, non-linear programming optimality conditions, gradient methods, and conjugate direction methods. Applications are considered; case studies included. Extensive paradigms from production planning and scheduling in manufacturing systems. Other illustrative applications include fleet management, air traffic flow management, optimal routing in communication networks, and optimal portfolio selection. Meets with ENG SE524 and EC674. Students in PhD program should register for EC674. Students may not receive credit for both. 4 cr.

ENG EC 527-A1 High Performance Programming with Multicore and GPUs **Prof. Herbordt**

Considers theory and practice of hardware-aware programming. Key theme is obtaining a significant fraction of potential performance through knowledge of the underlying computing platform and how the platform interacts with programs. Studies architecture of, and programming methods for, contemporary high-performance processors. These include complex processor cores, multicore processors, and graphics processors. Laboratory component includes use and evaluation of programming methods on these processors through applications such as matrix operations and the Fast Fourier Transform. 4 cr.

ENG EC 528-A1 Cloud Computing **Prof. Krieger**

Prereq:(ENGEC327 & ENGEC330) Undergrads must have taken EC327 or equivalent and preferably another software course, EC330 or EC440, before taking this course. Grad Prereq:(ENGEC504) Graduate students must have taken a rigorous programming class recently, such as EC504 or equivalent (or have major software design experience in industry). Fundamentals of cloud computing covering IaaS platforms, OpenStack, key Big Data platforms, and data center scale systems. Examines influential publications in cloud computing. Culminates in a group project supervised by a mentor from industry or academia. 4 cr.

ENG EC 533-A1 Advanced Discrete Mathematics **Prof. Levitin**

Prereq: (CASMA124) or equivalent Selected topics in discrete mathematics. Formal systems. Mathematical deduction. Logical concepts. Theorem proving. Sets, relations on sets, operations on sets. Functions, graphs, mathematical structures, morphisms, algebraic structures, semigroups, quotient groups, finite-state machines, their homomorphism, and simulation. Machines as recognizers, regular sets. Kleene theorem. 4 cr.

ENG EC 555-A1 Introduction to Biomedical Optics **Prof. Bigio**

Prereq: (ENGBE200 & CASMA226) ENG BE 200 or equivalent. CAS MA 226 and BE/EC 401 This course surveys the applications of optical science and engineering to a variety of biomedical problems, with emphasis on optical and photonics technologies that enable real, minimally-invasive clinical and laboratory applications. The course teaches only those aspects of the biology itself that are necessary to understand the purpose of the applications. The first weeks introduce the optical properties of tissue, and following lectures cover a range of topics in three general areas: 1) Optical spectroscopy applied to diagnosis of cancer and other tissue diseases; 2) Photon migration and diffuse optical imagine of subsurface structures in tissue; and 3) laser-tissue interactions and other applications of light for therapeutic purposes. Some classes will invoke traditional lectures, and others will be "inverted," devoted to discussing and understanding application problems, with students having read textbook sections or online material prior to class. 4 cr.

ENG EC 562-A1 Engineering Optics **Prof. Dal Negro**

Prereq: Matlab (or equivalent environment) programming, introductory electromagnetics, calculus I and II, vector calculus, complex variables and functions, linear algebra, Fourier transforms. The goal of this course is to present a coherent formulation of wave propagation, radiation and diffraction phenomena in arbitrary linear systems for the engineering design of optical devices in strong partnership with computer simulations and engineering-led design projects. The course will introduce students to the fundamental techniques that are necessary for the quantitative analysis of optics-based engineering systems and devices. 4 cr. 1st sem

ENG EC 565 Electromagnetic Fundamentals-A1 **Prof. Ramachandran**

Prereq: Consent of Instructor Fundamentals of electromagnetic theory as deduced from Maxwell's equations and material modeling; electromagnetic radiation and quasistatic limits in electromagnetic modeling. Radio frequency coaxial cables; VLSI interconnects, transmission lines. Waveguides and resonators; both dielectric and hollow. Particle tracking, plasmas, microwave sources, with applications. Depending on time and interest: numerical methods (variational formulations will be emphasized whenever practical), inverse problems; applications of magnetics and superconductivity.
4 cr.

ENG EC 573-A1 Solar Energy Systems **Prof. Mazumder**

Prereq:(ENGEK408) graduate standing or permission of the instructor. ENG EC 471 is suggested. This course is designed for first year graduate and senior undergraduate students from engineering disciplines. It is intended to educate students in the design and applications of solar energy technology. It will focus on fundamentals of solar energy conversion, solar cells, optical engineering, photoelectrochemical cells, thermoelectric generators, and energy storage and distribution systems. The course covers solar energy insolation and global energy needs, current trends in photovoltaic energy engineering, solar cell materials science, design and installation of solar panels for residential and industrial applications and connections to the national grid and cost analysis of the overall system. In addition, basic manufacturing processes for the production of solar panels, environmental impacts, and the related system engineering aspects will be included to provide a comprehensive state-of-the-art approach to solar energy utilization. Meets with ENG MS573; students may not take credit for both. 4 cr.

ENG EC 574-A1 Physics of Semiconductor Materials **Prof. Bellotti**

Prereq: (CASPY313 OR ENGEC410) or equivalent This course teaches the relevant notions of quantum

mechanics and solid state physics necessary to understand the operation and the design of modern semiconductor devices. Specifically, this course focuses on the engineering aspects of solid state physics that are important to study the electrical and optical properties of semiconductor materials and devices. Particular emphasis is placed on the analysis of the electronic structure of semiconductor bulk systems and low-dimensional structures, the study of the carrier transport properties and the calculation of the optical response that are relevant to the design and optimization of electronics and photonics semiconductor devices. The students will learn to apply the quantum mechanical formalism to the solution of basic engineering device problems (quantum wells, wires, and dots, 2D electron gas) and to perform numerical calculation on more complex systems (band structure calculation of bulk and low dimensional systems). 4 cr.

ENG EC 577-A1 Electronic Optical and Magnetic Properties of Materials **Prof. Swan**

Prereq:(CASPY313) or equivalent, ENG EC 574 suggested. This course in intended to develop an in depth knowledge of solid state concepts that are important for students in the areas of material science and electrical engineering. Specifically, this course focuses on the study of different apsect of solid state physics necessary to study technologically relevant crytalline and amorphous systems. Particular enphasis is placed on the study of the crystal structure, crystal diffraction and the related techniques used as diagnostic tools; the electronic, thermal, optical and magnetic properties of material systems important for electronics and photonics device applications. Furthermore the course will also consider the theory of superconductivity, the chemistry aspcts of solid state materials and will provide an introduction to solid state biophysics. This course complements EC 574 (Physics of semiconductor material) and EC575 (semiconductor devices) with its focus on technologically relevant structural, optical, thermal and magnetic material properties. Meets with ENG MS 577. Students may not receive credit for both. 4 cr.

ENG EC 578-A1 Fabrication Technology for Integrated Circuits **Prof. Kleptsyn**

Prereq: (ENGEC410) Coreq:(ENGEC410) Presentation of fabrication procedures for silicon-integrated circuits: physical properties of bulk and epitaxially grown silicon; silicon processing, such as oxidation, diffusion, epitaxy, deposition, and ion implantation; silicon crystallography, anisotropic etching, photolithography, piezorestivity, and chemical and plasma techniques. The limitations these processes impose on the design of bipolar and MOS devices and integrated circuits are discussed. Design of an integrated circuit and the required processing. Includes lab. 4 cr.

ENG EC 579-A1 Nano/microelectronic Device Technology **Prof. Cole**

Prereq: Graduate standing plus an undergraduate course in semiconductors at the level of ENGEC410, ENGEC471, CASPY313, or CASPY354, or consent of instructor. The main physical processes and manufacturing strategies for the fabrication and manufacture of micro and nanoelectronic devices will be covered, mostly for silicon, although exciting materials such as graphene and carbon nanotubes will also be covered. A key emphasis here will be on electron-hole transport, band structure, basic quantum effects, and the use of engineering and physical effects to alter semiconductor device performance. Photolithography, a significant factor in manufacturability, will be covered in some detail, and to a lesser degree, so will doping methods, diffusion, oxidation, etching, and deposition. The overall integration with methods and tools employed by device and circuit designers will be covered. Same as ENGME579. Students may not receive credit for both employed by device and circuit designers will be covered. Same as ENGME579. Students may not receive credit for both. 4 cr.

ENG EC 580-A1 Analog VLSI Circuit Design…… ……Prof. Yazicigil Ki
Prereq: (ENGEC412) Anatomy of an operational amplifier using chip design techniques. Applications of op amps in wave-shaping circuits, active filters including capacitive switching. Analog multiplexing and data acquisition circuits, A/D, D/A, S/H are examined. Frequency selective circuits and interface circuits such as optocouplers are analyzed. 4 cr.

ENG EC 591-A1 Photonics Lab I Prof. Paiella
Prereq:(CASPY313) Coreq:(ENGEC562) *Introduction to optical measurements. Laser safety issues. Laboratory experiments: introduction to lasers and optical alignment; interference; diffraction and Fourier optics; polarization components; fiber optics; optical communications; beam optics; longitudinal laser modes. Optical simulation software tools. 4 cr.
Students registering for ENG EC591 must register for two sections: a lecture section and a lab section.

ENG EC 601-A1 and –A2 Product Design in Electrical and Computer Engineering Prof. Alshaykh
Prereq: Graduate Standing or permission of instructor. Engineers influence their community, society and the world. Engineers build products and services that can enhance people's lives. The product starts with an idea and is delivered through research (technical and societal), design, implementation, testing and support. During this class, students will experience all of this. The course provides design and practical insights into building products that involve WEB and mobile app development, data simulation, analysis and modeling, cloud computing, signal processing and/or computer vision. In the class, we work on how to take an idea and concept and translate it into product requirements. Afterwards, we translate the product requirements into system and engineering requirements. We also discuss solution selection techniques. We then work on implementing our ideas into systems and verify that they address the product requirements and fulfill the concept we started with. During the class, we go over how to choose solutions to build our products. We also discuss real product realization, implementations and tradeoffs. The class is taught via an example product and the class sessions are interactive. Students are divided into groups where they work in parallel on their projects during class sessions and hackathons. Teams define their target audience, product mission, requirements and features. The class adopts agile software development based on a two-week sprint. Students present their sprint results to the class. 4 cr.

ENG EC 602-A2 Design by Software Prof. Carruthers
Prereq: Graduate standing or permission of instructor. Software plays a central role in all aspects of electrical and computer engineering. This course will provide the foundation for effectively using software as a key part of a career as a professional electrical or computer engineer. Fundamentals of software development systems: system languages, high-level object-oriented languages, and computational languages. Data structures and algorithms in problem analysis and design. Strategies for designing software and designing with software. Software design and development: methodologies, principles and practice. Formalizing software: management, requirements, specifications, testing. Survey of software applications in ECE, including real-time systems, the web, networked systems, audio, graphics, and video systems, research and engineering analysis, consumer electronics and computing, instrumentation and measurement, design, modeling, prototyping, simulation, optimization and information analysis. Students can choose projects and assignments with application to/inspired by/drawn from a broad array of ECE fields including the traditional areas of electro-physics/photonics, computer engineering, and information and data science. 4 cr.

ENG EC 605-A1 Computer Engineering Fundamentals **Prof. Moreshet**

This is an introductory course to computer engineering, focusing on the hardware/software interface, and presenting a bottom-up view of a computer system. Topics include logic design: binary arithmetic, combinational and sequential logic. Computer organization: assembly language programming, CPU design, and memory systems. Introduction to compilers, operating systems, and computer networks. 4 cr.

EC700-S6 Internet of Things Security **Prof. Starobinski**

The purpose of this course is to expose students to new developments in the areas of cybersecurity and the Internet of Things (IoT). In this first offering of the course, the topics to be covered include credential management systems for connected devices, blockchains, and software-defined radios. The course will blend theory and practice. Students will design hands-on labs to be performed by other students in the course and conduct a research project, building on recent results from the literature.

ENG EC 701-A1 Optimal and Robust Control **Prof. Andersson**

Prereq:(ENGEC501 OR ENGME501 OR ENGSE501) This course is aimed at an introduction (with rigorous treatment) to the fundamentals of optimal and robust control. It will be divided roughly into two parts. The first will cover aspects of robust control including model reduction, H_2 and H_ infinity control, and feedback control of uncertain systems. The second will delve into optimal control including topics such as the linear quadratic regulator, the calculus of variations, the maximum principle, and the Hamilton-Jacobi-Bellman equation. Meets with ENG ME701 and ENG SE 701; only one of these courses may be taken both for credit. 4 cr.

ENG EC 702-A1 Recursive Estimation and Optimal Filtering **Prof. Castanon**

Prereq: (ENGEC505) *State-space theory of dynamic estimation in discrete and continuous time. Linear state-space models driven by white noise, Kalman filtering and its properties, optimal smoothing, non-linear filtering, extended and second-order Kalman filters, and sequential detection. Applications to radar, sonar, and optimal multitarget tracking, parameter identification. 4 cr.

ENG EC 754-A1 Computer-Aided Verification and Synthesis **Prof. Li**

Prereq: (ENGEC330) Familiarities of propositional logic, basic probability theory and basic graphic graph algorithms, and experience with one programming language (e.g., C++, Python) are assumed. An undergraduate course This course will introduce the fundamental theory in computer-aided verification and synthesis for building provably dependable computer systems. The topics covered include logic specifications, modeling formalisms, verification techniques, and inductive synthesis strategies. A special focus of the course is on interplay between deductive reasoning (logical inference and constraint solving) and inductive inference (learning from data). We will also survey applications of these techniques to a wide range of problems in hardware, software, cyber-physical systems, robotics, and biology. 4 cr.

ENG EC 762-A1 Quantum Optics **Prof. Sergienko**

Prereq: (ENGEC560) or equivalent, or consent of instructor. *Review of the postulates of quantum mechanics. Quantization of the electromagnetic field. Coherent, thermal, squeezed, and entangled states, and their associated photon statistics. Interaction of light with matter. Spontaneous and stimulated transitions. Theory of optical detection. Quantum theory of the laser. Interaction of light

with two-level atoms, including photon echo and self-induced transparency. Quantum theory of parametric interactions. 4 cr.