ECE MS Program in Electrical and Computer Engineering
Spring 2021 Course Offerings

ENG EC 500-A1 Special Topics in ECE: Optimization for Machine Learning **Prof. Cutkosky**
Prerequisites: Ability to program in Python. Some experience with linear algebra, calculus, and probability. Example concepts that should be familiar include gradients, eigenvectors, eigenvalues, Taylor series, and expectations.

Efficient algorithms to train large models on large datasets have been critical to the recent successes in machine learning and deep learning. This course will introduce students to both the theoretical principles behind such algorithms as well as practical implementation considerations. Topics include convergence properties of first-order optimization techniques such as stochastic gradient descent, adaptive learning rate schemes, and momentum. Particular focus will be given to the stochastic optimization problems with non-convex loss surfaces typically present in modern deep learning problems. Additional topics may include second-order methods and variance reduction. After completing this course, students should be able to read, understand, and implement cutting-edge optimization algorithms used in machine learning. 4cr.

ENG EC 500-A2 Special Topics in ECE: Software Engineering Principles **Prof. Alshaykh**
EC500 C1 focuses on developing product quality software. The class builds on EC601 and EC602. In the class, we will focus on software development principles, techniques and principles. We will focus on modular design concepts, product quality (testing framework, unit testing), debugging, concurrency, data flow, and API design. We will use state-of-art open source projects to learn and master different skills. 4cr.

This class is designed where students prepare before class and work on the principles during the class. The class also includes a project that is assigned at the beginning and discussed every other week in the class. 4cr.

ENG EC 500-L6 Special Topics in ECE: Plasma Engineering and Technologies **Prof. M.C. Lee**
Prerequisites: ENG EC455 "Electromagnetics Systems" required for Undergraduate students. Electrodynamics is the background knowledge for the "Plasma Engineering and Technologies" course. Hence, Maxwell equations and some related time-varying electromagnetic phenomena in a medium will be reviewed. However, plasma as a quasi-neutral medium with charged particles behaves differently from a magnetic material with a permeability, while it is still appropriate to derive a plasma dielectric constant. These distinctive features will be elaborated in this course at the beginning.

(1) Course Goals: Teaching fundamentals of plasma engineering and experiments as well as selected technologies including plasma photonics and nanotechnology, plasma medicine, spacecraft propulsion, laser and magnetic fusion, and solar powered microwave transmission systems."

(2) Course Topics: "Plasma fundamentals, plasma waves, plasma-electromagnetic wave and plasma-electrostatic wave interactions, diagnostic techniques in plasmas, plasma-based technologies, such as nanotechnology, photonics, plasma medicine, spacecraft propulsion, laser and magnetic fusion, and solar powered microwave transmission systems."

(3) Textbook: "Plasma Engineering" by Michael Keidar and Isak Beilis, Academic Press, 2018, ISBN: 9780128137024 and Instructor's Lecture Notes. 4cr.

ENG EC 503-A1 Introduction to Learning from Data **Prof. Orabona**
Prerequisite: ENG EK381

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. Castanon**

Prerequisite: ENG EC330

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 512-A1 Enterprise Client-Server Software Systems Design **Prof. Skinner**

Prerequisites: Senior standing or consent of instructor, programming experience in C++, Java, or C#, basic knowledge of internet protocols and HTML, ENGEC440 or equivalent is required. ENGEC441 ENGEC447 are recommended

Examination of past, current, and emerging technologies. Client side technologies including DHTML, CSS, scripting, ActiveX, RSS, and proprietary applications. Legacy server side technologies including CGI, ISAPL, and active server pages. Current and emerging server technologies including ASP.NET 2, XML/SOAP web services, wireless and handheld access, WAP/WML, SQL databases, streaming media, CMS, and middleware. Design and implementation of solutions involving database connectivity, session state, security requirements, SSL, and authentication of clients. Small-team projects involving design through implementation. 4cr.

ENG EC 520-A1 Digital Image Processing and Communication **Prof. Konrad**

Prerequisites: ENG EC504 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 521-A1 Cybersecurity **Prof. Trachtenberg**

Prerequisites: ENG EC 327; ENG EC 441.

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 522-A1 Computational Optical Imaging **Prof. Tian**

Prerequisites: ENG EK 103 ; ENG EK 125 ; ENG EC 401; EK 102 or EK 103 or MA 142 or equivalent; EK 125 or EK 127 or equivalent; EC 401 or equivalent

Recent years have seen the growth of computational optical imaging - optical imaging systems that tightly integrate hardware and computation. The results are the emergence of many new imaging capabilities, such as 3D, super resolution, and extended depth of field. Computational optical imaging systems have a wide range of applications in consumer photography, scientific and biomedical imaging, microscopy, defense, security and remote sensing. This course looks at this new design approach as it is applied to modern optical imaging, with a focus on the tools and techniques at the convergence of physical optical modeling, and signal processing. 4 cr.

ENG EC 526-A1 Parallel Programming for High Performance Computing **Prof. Brower**

The explosive advance in High Performance Computing (HPC) and advances in Big Data/Machine Learning and Cloud Computing now provides a fundamental tool in all scientific, engineering, and industrial advances. Software is massively parallel so parallel algorithms and distributed data structures are required. Examples will be drawn from FFTs, Dense and Sparse Linear Algebra, Structured and unstructured grids. Techniques will be drawn from real applications to simple physical systems using Multigrid Solvers, Molecular Dynamics, Monte Carlo Sampling and Finite Elements with a final student project and team presentation to explore one example in more detail. Coding exercises will be in C++ in the UNIX environment with parallelization using MPI message passing, OpenMP threads and QUDA for GPUs. Rapid prototypes and graphics may use scripting in Python or Mathematica. 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 534-A1 Discrete Stochastic Models **Prof. Levitin**
Prerequisites: ENG EC381 OR ENG EK500
Markov chains, Chapman-Kolmogorov equation. Classification of states, limiting probabilities, Poisson process and its generalization, continuous-time Markov chains, queuing theory, reliability theory. 4 cr.

ENG EC 535-A1 Introduction to Embedded Systems **Prof. Coskun**
Prerequisites: ENG EC311 OR ENG EC327 OR ENG EC605 or equivalent; basic knowledge of assembly languages, computer organization and logic circuits, basic knowledge of data structure and algorithms, programming skills in C/C++. Grad Prereq:(ENGEC311 OR ENGEC327 OR ENGEC605) or equivalent; basic knowledge of assembly languages, computer organization and logic circuits, basic knowledge of data structure and algorithms, programming skills in C/C++.
This course introduces students to a unified view of hardware and software in embedded systems. The lectures will survey a comprehensive array of techniques including system specification languages, embedded computer architecture, real-time operating systems, hardware-software codesign, and co-verification techniques. The lectures will be complemented by assignments and projects that involve system design, analysis, optimization, and verification. 4 cr.

ENG EC 544-A1 Networking the Physical World **Prof. Montazam**
Prerequisites: ENG EC327 ENG EC 441 recommended, C programming experience required.
Considers the evolution of embedded network sensing systems with the introduction of wireless network connectivity. Key themes are computing optimized for resource constrained (cost, energy, memory and storage space) applications and sensing interfaces to connect to the physical world. Studies current technology for networked embedded network sensors including protocol standards. A laboratory component of the course introduces students to the unique characteristics of distributed sensor motes including programming, reliable communication, sensing modalities, calibration, and application development. Meets with ENGME544. Students may not receive credit for both. 4 cr.

ENG EC 552-A1 Computational Synthetic Biology for Engineers **Prof. Densmore**
This course presents the field of computational synthetic biology through the lens of four distinct activities: Specification, Design, Assembly, and Test. Engineering students of all backgrounds are provided an introduction to synthetic biology and then exposed to core challenges and approaches in each of the four areas. 4cr.

ENG EC 556-A1 Optical Spectroscopic Imaging **Prof. Cheng**
Grad Prerequisites: ENG EK125 & CASPY212, EK 125 or equivalent Matlab; PY 212 or equivalent knowledge of light and waves. Suggested: EC 562, EC 555

This introductory graduate-level course aims to teach students how electromagnetic waves and various forms of molecular spectroscopy can be used to study a complex biological system by pushing the physical limits on engineering system design.The course will cover fundamental concepts of optical spectroscopy and microscopy, followed by specific topics covering fluorescence-based , absorption-based, and scattering-based spectroscopic imaging. In addition, this course will provide in-depth discussions of linear and nonlinear spectroscopic imaging in the aspects of theory, instrumentation, image data analysis and enabling applications. Students will learn how to give a concise and informative presentation of a recent literature to the class. Students will be able to challenge their creativity in designing advanced imaging instrument of data analysis methods as part of their course assignments. The students will learn how to write and present a convincing proposal for the required final project to be designed by interdisciplinary teams formed among the students. 4 cr.

ENG EC 568-A1 Optical Fibers and Wave Guide **Prof. Popovic**

Prerequisites: ENG EC455 or consent of instructor

Whether it be the FIOS? internet connection at our homes, or fiber lasers powerful enough to cut metals (many automobile chassis are now made using fiber lasers), or the ability to perform endoscopic surgery and imaging, or doing frequency metrology with super-continuum sources (the basis of a few recent Nobel prizes)... the optical fiber has played a central, often dominant, role in many applications that impact the way we live. The main function of an optical fiber is to carry an electromagnetic (in the optical frequency) pulse over distances ranging from meters to greater than ten thousand kilometers without distortions. Fibers can also become smart light-pipes when they are intentionally designed to alter, temporally shape or amplify light pulses. Moreover, new developments in this field such as photonic bandgap fibers, fiber nanowires and higher-order mode fibers, are opening up new directions in science and technology. This course will introduce the optical fiber waveguide and its theory of operation. Specifically, the design and impact of the two most important properties in optical fibers -- dispersion and nonlinearity -- that govern the evolution of light in optical fibers, will be covered in detail. The latter part of the course will describe new fibers and fiber-structures that are active research topics today. One lecture of the course will include a tour of an actual, industrial-scale fiber fabrication facility. 4 cr.

ENG EC 570-A1 Lasers and Applications **Prof. Ndao**

Prerequisite: ENG EC455

Review of wave optics. Gaussian, Hermite-Gaussian, Laguerre-Gaussian, and Bessel optical beams. Planar- and spherical-mirror resonators; microresonators. Photons and photon streams. Energy levels; absorption, spontaneous emission, and simulated emission. Thermal and scattered light. Laser amplification and gain saturation. Laser oscillation. Common lasers and introduction to pulsed lasers. Photon interactions in semiconductors. LEDs, laser diodes, quantum-confined lasers, and microcavity lasers. Introduction to photon detectors. Laboratory experiments: beam optics; longitudinal laser modes; laser-diode output characteristics.4 cr.

ENG EC 571-A1 Digital VLSI Circuit Design **Prof. Joshi**

Prerequisites: ENG EC311 & ENG EC410

Very-large-scale integrated circuit design. Review of FET basics. Functional module design, including BiCMOS, combinational and sequential logic, programmable logic arrays, finite-state machines, ROM, and RAM. Fabrication techniques, layout strategies, scalable design rules, design-rule checking, and guidelines for testing and testability. Analysis of factors affecting speed of charge transfer, power requirements, control and minimization of parasitic effects, survey of VLSI applications. Extensive CAD laboratory accompanies course. 4 cr.

ENG EC 575-A1 Semiconductor Devices **Prof. Bellotti**

Prerequisites: ENG EC410 & ENGEC455 & ENGEC574 & CASPY313 or equivalent.

Fundamentals of carrier generation, transport, recombination, and storage in semiconductors. Physical principles of operation of the PN junction, metal-semiconductor contact, bipolar junction transistor, MOS capacitor, MOSFET (Metal Oxide Semiconductor Field Effect Transistor), JFET (Junction Field Effect Transistor), and bipolar junction transistor. Develops physical principles and models that are useful in the analysis and design of integrated circuits. 4 cr.

ENG EC 700 Advanced Topics in Electrical and Computer Engineering: Introduction to Reinforcement Learning
Prof. Olshevsky

Prerequisites: Graduate standing or consent of instructor. *Advanced topics of current interest in electrical and computer engineering.

Reinforcement learning is a subfield of artificial intelligence which deals with learning from repeated interactions with an environment. Reinforcement learning is the basis for state-of-the-art algorithms for playing strategy games such as Chess, Go, Backgammon, and Starcraft, as well as a number of problems throughout robotics, operations research, and other fields of engineering. In this course, we will study the fundamental principles of reinforcement learning. Our focus will be the main algorithms in the field: we'll try to develop a mathematical understanding of why they work. While a moderate amount of coding will be required, the most important pre-requisite is mathematical maturity and a facility with constructing proofs. The course webpage is http://sites.bu.edu/aolshevsky/foundations-of-reinforcement-learning/. 4 cr.

ENG EC 700 Advanced Topics in Electrical and Computer Engineering: Cyber-Physical Systems and Autonomous Vehicles
Prof. Cassandras

Prerequisites: Graduate standing or consent of instructor. *Advanced topics of current interest in electrical and computer engineering.

This is a course for graduate students interested in the state of the art in the theory and applications of Cyber-Physical Systems (CPS) with emphasis on networked autonomous vehicles as one instance of CPS. The course will examine these systems from a modeling, control, and optimization standpoint and place them in a unifying multi-agent network system framework. The purpose is to learn about advanced methodologies used in CPS and about open research problems, and to critically review and present papers from the very recent literature. Students will develop the ability to conceptualize cutting-edge research issues in the CPS, networked multi-agent system, and cooperative control domains, with emphasis on autonomous vehicles, as well as to formulate problems for potential research projects. 4 cr.

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

Prerequisites: ENG EC 505.

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. 4cr.

ENG EC 707-A1 Radar Remote Sensing **Prof. Semeter**

Prerequisites: Experience in electromagnetic waves, analog and discrete signal processing, or consent of the instructor.

Principles of radar systems and radar signal analysis with emphasis on environmental remote sensing. Topics include antenna fundamentals, wave propagation/scattering in various media, the radar equation, radar cross-section, target characteristics, ambiguity function, radar system components, pulse compression techniques, and aperture synthesis. Highlighted systems include ground-penetrating radars, synthetic aperture radar (SAR), weather radars, and incoherent scatter radars, and LIDAR. 4cr.

ENG EC 716-A1 Advanced Digital Signal Processing **Prof. Nawab**

Prerequisites: ENG EC 516.

Selected topics from time-frequency distributions, parametric signal modeling, high-resolution spectral estimation, multi-rate signal processing, multidimensional signal processing, adaptive signal processing, alternative algorithms for DFT computation, symbolic and knowledge based signal processing. Application examples chosen from speech, image, communication, and biomedical applications. 4cr.

ENG EC 719-A1 Statistical Pattern Recognition **Prof. Ishwar**

Prerequisites: ENG EK 500; ENGEC381 or ENGEK381
Corequisites: ENG EC 505.
The statistical theory of pattern recognition, including both parametric and nonparametric approaches to classification. Covers classification with likelihood functions and general discriminant function, density estimation, supervised and unsupervised learning, decision trees, feature reduction, performance estimation, and classification using sequential and contextual information, including Markov and hidden Markov models. A project involving computer implementation of a pattern recognition algorithm is required. 4 cr.

ENG EC 724-A1 Advanced Optimization Theory and Methods **Prof. Paschalidis**

Prerequisites: ENG EC 524; consent of instructor
Introduces advanced optimization techniques. Emphasis on nonlinear optimization and recent developments in the field. Topics include: unconstrained optimization methods such as gradient, conjugate direction, Newton and quasi-Newton methods; constrained optimization methods such as gradient projection, feasible directions, barrier and interior point methods; duality theory and methods; convex duality; and introduction to other advanced topics such as semi-definite programming, incremental gradient methods and stochastic approximation algorithms. Applications drawn from control, production and capacity planning, resource allocation, communication and neural network problems. Meets with ENGME724 and ENGSE724. Students may not receive credit for both. 4 cr.

ENG EC 777-A1 Nanostructure Optics **Prof. Dal Negro**

Prerequisites: ENG EC 560 or ENG EC 568.
Discussion of the fundamental physical aspects and device applications of optical fields confined and generated in nanoscale environments. Review of classical electrodynamics and angular spectrum representation of optical fields, classical and quantum models for light-matter interaction, light emission from semiconductor quantum dots and wires, surface-plasmon polaritons and sub-wavelength light transport/localization in metal nanostructures, slot waveguide structures, surface-enhanced Raman scattering (SERS) and SERS-based sensors, light scattering in complex photonic structures such as: metal-dielectric photonic crystals, fractal structrures, random lasers. 4 cr.