DIGITAL HEALTH

Contact Information

Electrical and Computer Engineering
https://www.ece.rice.edu/
429A O'Connor Building for Engineering and Science
713-348-5081

Ashok Veeraraghavan
Department Chair, Electrical and Computer Engineering
vashok@rice.edu

Jose Roberto Moreto
Program Co-Director, DIGH Minor
jm257@rice.edu

Akane Sano
Program Co-Director, DIGH Minor
akane.sano@rice.edu

Ashutosh Sabharwal
Program Director, MDH Degree
ashu@rice.edu

Digital Health is a broad and interdisciplinary field that encompasses areas such as artificial intelligence, assistive technologies, medical imaging, health equity, robotics, sensors, wearables, and ingestible electronics. As an emerging field, it refers to the use of digital technologies to monitor, manage, and improve health outcomes. This includes tools such as wearable/indigestible sensors, mobile health apps, telemedicine, robotics, imaging technologies, and AI-driven healthcare solutions. The goal of digital health is to transform healthcare from episodic care to continuous care, making it more accessible, efficient, and personalized. By leveraging technology, digital health aims to provide equitable healthcare, enhance patient engagement, improve disease management, and support preventive care.

As a program, Digital Health is overseen by the Department of Electrical and Computer Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/). At the undergraduate level, the department offers a minor in Digital Health. At the graduate level, the department offers a Master of Digital Health (MDH) degree.

Minor

- Minor in Digital Health (https://ga.rice.edu/programs-study/departments-programs/engineering/digital-health/digital-health-minor/)

Master's Program

- Master of Digital Health (MDH) Degree (https://ga.rice.edu/programs-study/departments-programs/engineering/digital-health/digital-health-mdh/)

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Steering Committee, *DIGH Minor*

Joseph R. Cavallaro, *Electrical and Computer Engineering*
Meng Li, *Statistics*
Marcia K. O'Malley, *Mechanical Engineering*
Ashutosh Sabharwal, *Electrical and Computer Engineering*
Todd Treangen, *Computer Science*

For Rice University degree-granting programs:
To view the list of official course offerings, please see Rice's Course Catalog (https://courses.rice.edu/admweb/!SWKSCAT.cat?p_action=cata).
To view the most recent semester's course schedule, please see Rice's Course Schedule (https://courses.rice.edu/admweb/!SWKSCAT.cat).

Electrical and Computer Engineering (ELEC)

ELEC 220 - FUNDAMENTALS OF COMPUTER ENGINEERING
Short Title: FUND COMPUTER ENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: An overview of computer engineering, starting with fundamental building blocks including transistors, bits, data representation, logic and state machines, progressing to computer organization, instruction sets, interrupts, input/output, assembly language programming, and linkage conventions, and ending with an introduction to architectural performance enhancements and computing services.
Course URL: www.owlnet.rice.edu/~elec220 (http://www.owlnet.rice.edu/~elec220/)

ELEC 238 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Laboratory, Lecture, Seminar, Independent Study
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Repeatable for Credit.

ELEC 240 - FUNDAMENTALS OF ELECTRICAL ENGINEERING I LABORATORY
Short Title: FUND EE I LAB
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): (MATH 101 or MATH 105) and (MATH 102 or MATH 106)
Corequisite: ELEC 241
Description: Laboratory course that introduces basic electronic measurement techniques and demonstrates the principles of information management by electronic means. Lectures supplement the laboratory experiments.

ELEC 241 - FUNDAMENTALS OF ELECTRICAL ENGINEERING I
Short Title: FUND ELECTRICAL ENGINEERING I
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): (MATH 101 or MATH 105) and (MATH 102 or MATH 106)
Corequisite: ELEC 240
Description: The creation, manipulation, transmission, and extraction of information by electronic and computational means. Elementary signal theory; time and frequency-domain analysis; sampling theorem. Introduction to data science. Information theory; digital communication systems; error-correcting codes.

ELEC 242 - SIGNALS, SYSTEMS, AND TRANSFORMS
Short Title: SIGNALS, SYSTEMS, & TRANSFORMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): ELEC 241
Corequisite: ELEC 244
Description: Transforms between the time and frequency domains. Linear time-invariant systems: convolutions, impulse response, and eigenfunctions. Delta functions, their nature, and their uses. Fourier series and the Fourier transform for continuous signals. Fourier transform for discrete-time signals. Sampling and aliasing. Laplace transform: poles and zeros, and system stability. Students must register for both ELEC 242 and ELEC 244.

ELEC 243 - ELECTRONIC MEASUREMENT SYSTEMS
Short Title: ELECTRONIC MEASUREMENT SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Distribution Group: Distribution Group III
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and (PHYS 102 or PHYS 112 or PHYS 126)
Description: The course will give students the skills to design, construct, and assess electronic systems to measure, monitor, and control physical properties and events; spans the areas of circuits, signals, systems, and digital processing. Intended for non-ECE majors.

ELEC 244 - ANALOG CIRCUITS LABORATORY
Short Title: ANALOG CIRCUITS LABORATORY
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Corequisite: ELEC 242
Description: Lab skills covered including breadboarding, use of oscilloscopes, and circuit debugging. Topics covered include design, construction, and testing of basic electronic circuits; RLC networks; diodes; transistors; operational amplifiers; comparators; interfacing digital and analog circuits; pulse width modulation; motors; and feedback control. Students must register for both ELEC 242 and ELEC 244.

ELEC 261 - INTRODUCTION TO PHYSICAL ELECTRONICS I
Short Title: INTRO PHYSICAL ELECTRONICS I
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): (MATH 102 or MATH 106) and (PHYS 102 or PHYS 112)
Description: The objective of this course is an understanding of the physics and operation of semiconductor de-vices. The first part of 261 is focused on understanding of semiconductor materials in terms of crystal structure, energy bands, density of states, dopants, and electronic transport, and finally the basics of pn junctions and pn junction diodes. The second part of 261 is focused on understanding the operation and design of semiconductor devices including metal-semiconductor contacts, metal-oxide semi-conductor capacitors and transistors (MOSFETs), and bipolar junction transistors (BJTs). In addition, 261 will also introduce the basic concepts of advanced devices such as junction field effect transistors, optical devices, microwave and power devices. ELEC 261 will lay the foundation for follow-on PEN and circuits courses such as ELEC 305.

ELEC 262 - INTRODUCTION TO WAVES AND PHOTONICS
Short Title: INTRO TO WAVES AND PHOTONICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) and (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142)
Description: Introduction to the concepts of waves and oscillatory motion with a particular focus on electromagnetic waves and their interaction with dielectric materials, and on the use of these ideas in the fields of optical fiber communications, laser design, non-linear optics and Fourier optics. Introduction to photons as carriers of electromagnetic energy with related examples of quantum phenomena.

ELEC 263 - INTRODUCTION TO PHYSICAL ELECTRONICS LAB
Short Title: INTRO TO PHYS ELECTRONICS LAB
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): ELEC 261 and MATH 212 (may be taken concurrently)
Description: This is a 1-credit lab course that covers the fundamental physics of electronic devices. Topics include: physics of semiconductor devices including diodes, transistors and solar cells; Maxwell's equations, transmission lines, and antenna radiation. Students will complete about 4-5 lab measurements over the course of the semester. The course will include some short talks on current research by Rice faculty. Groups of students will prepare a short video presentation on current topics.

ELEC 301 - SIGNALS, SYSTEMS, AND LEARNING
Short Title: SIGNALS, SYSTEMS, AND LEARNING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 241 and (MATH 354 or MATH 355 or CAAM 334 or CAAM 335 or CMOR 302 or CMOR 303)
Corequisite: ELEC 303
Description: Analytical framework for analyzing signals and systems. Time and frequency domain analysis of continuous and discrete time signals and systems, convolution, and the Laplace and Z transforms. Introduction to algorithms for machine learning on signals, including clustering, regression, and classification. Instructor Permission Required.

ELEC 303 - RANDOM SIGNALS IN ELECTRICAL ENGINEERING SYSTEMS
Short Title: RANDOM SIGNALS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An introduction to probability theory and statistics with applications to electrical engineering problems in signal processing, communications and control; probability spaces, conditional probability, independence, random variables, distribution and density functions, random vectors, signal detection and parameter estimation. Instructor Permission Required.

ELEC 305 - INTRODUCTION TO PHYSICAL ELECTRONICS II
Short Title: INTRO PHYSICAL ELECTRONICS II
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 261
Description: Physical principles and practical applications of devices used in modern electronic systems, with an emphasis on transistors, integrated circuits, electromagnetic propagation, and transmission lines.

ELEC 323 - PRINCIPLES OF PARALLEL PROGRAMMING
Short Title: FUNDAMENTALS OF PARALLEL PROG
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 215
Description: Fundamentals of parallel programming: abstract models of parallel computers, parallel algorithms and data structures, and common parallel programming patterns including task parallelism, undirected and directed synchronization, data parallelism, divide-and-conquer parallelism, and map-reduce. Laboratory assignments will explore these topics through the use of parallel extensions to the Java language. Cross-list: COMP 322.

ELEC 326 - DIGITAL LOGIC DESIGN
Short Title: DIGITAL LOGIC DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 220 or COMP 222
Description: Study of gates, flip-flops, combinational and sequential switching circuits, registers, logical and arithmetic operations, introduction to the Verilog hardware description language. Cross-list: COMP 326.

ELEC 327 - IMPLEMENTATION OF DIGITAL SYSTEMS
Short Title: IMPLEMENTATION OF DIGITAL SYS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 326 or COMP 326
Description: Embedded microsystems are widely employed to provide intelligence to sensors and actuators throughout our daily life. In this course, we learn the software and hardware frameworks which underly embedded systems design. Students will learn the fundamentals of embedded system programming and feel competent to design, build, and manufacture their own embedded devices. In particular, we focus on principles of low-power design and interface with external peripherals. In addition, students will learn how to design their own manufacturable hardware and discover how application-specific blocks enable modern commercial devices to function. There are weekly lab assignments and two projects. Instructor Permission Required.

ELEC 328 - REAL-TIME RENDERING SYSTEMS
Short Title: REAL-TIME RENDERING SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 140 and (ELEC 220 or COMP 222)
Description: This course bridges the fundamentals of real-time graphics pipelines with practical experience in game engines, shader programming, XR (AR/VR), projection mapping, and virtual production. Students will combine technical depth in rendering software and hardware systems with creative, interactive applications. Hands-on projects using modern tools, such as the Unity Engine, GLSL/HLSL, and real-time GPU profilers, will emphasize system performance and perceptual feedback in immersive environments.

ELEC 361 - QUANTUM MECHANICS FOR ENGINEERS
Short Title: QUANTUM MECHANICS FOR ENGINEER
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 261
Description: This course provides the background in quantum mechanics and solid state physics necessary for further studies in semiconductor optoelectronic devices, quantum electronics, nanoscience, and photonics. Examples include: electronic energy levels in semiconductor quantum wells and superlattices; tunneling phenomena in semiconductor devices; the Kronig-Penney model; crystal momentum, effective mass, and Bloch oscillations; band structure of graphene and carbon nanotubes; and introduction to quantum information science.

ELEC 364 - PHOTONICS MEASUREMENTS: PRINCIPLES AND PRACTICE
Short Title: PHOTONICS MEASUREMENTS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 262 or PHYS 201
Description: After completing this course, students will have the knowledge and experimental skills to design and apply a photonic measurement system to monitor an environment, process, device, or system. The course will combine predefined labs to develop skills with application projects. Instructor Permission Required.

ELEC 378 - MACHINE LEARNING: CONCEPTS AND TECHNIQUES
Short Title: MACHINE LEARNING CONCEPTS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): MATH 355 or MATH 354 or CAAM 335 or CMOR 302 or CAAM 334 or CMOR 303
Description: This course deals with machine learning, from its theoretical mathematical foundations to practical implementation in computer algorithms for data science applications. The course follows a deterministic rather than probabilistic approach to focus on the key concepts; linear algebra plays a starring role.

ELEC 380 - INTRODUCTION TO NEUROENGINEERING: MEASURING AND MANIPULATING NEURAL ACTIVITY
Short Title: INTRO TO NEUROENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) and (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142) and (COMP 140 or CAAM 210 or CMOR 220)
Description: This course will serve as an introduction to quantitative modeling of neural activity and the methods used to stimulate and record brain activity. Cross-list: BIOE 380, NEUR 383. Graduate/Undergraduate Equivalency: ELEC 587. Mutually Exclusive: Cannot register for ELEC 380 if student has credit for ELEC 587.

ELEC 383 - WEARABLE BIOSENSORS
Short Title: WEARABLE BIOSENSORS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is designed to provide students with the tools to understand the basic parts of a wearable biosensor, including the biorecognition layer, transducer, signal output, the requirements for a wearable device, and the biofluids potential and limitations including discussion about biosensors for sweat, saliva, tears, interstitial fluid, urine, blood etc.

ELEC 384 - MACHINE LEARNING OF BIOMEDICAL TIME SERIES
Short Title: ML OF BIOMEDICAL TIME SERIES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Biomedical signals representing physiological processes help advance scientific understanding of the human body as well as enable translational/therapeutic applications. This course will introduce signal processing and machine learning methods for analyzing biomedical time series. First, students will gain an understanding of how common biological signals such as neural activity and muscle activity are generated and the typical issues with recording them (signal dispersion, recording instabilities, data scarcity, individual variability, etc). Second, they will learn commonly used statistical methods used to extract useful information from these biomedical signals. Methods will span spectral analysis, unsupervised discovery & latent variable models to identify structure in data and supervised methods to decode task-relevant information. While we focus on neurophysiological signal processing applications, the concepts are broadly applicable. Recommended Prerequisite(s): ELEC 303 Random Signals, probability or equivalent, ELEC 378 Fundamentals of Machine Learning, or equivalent, and ELEC 242 Signals, Systems and Transforms

ELEC 395 - TRANSFER CREDIT - JUNIOR
Short Title: TRANSFER CREDIT - JUNIOR
Department: Electrical & Computer Eng.
Grade Mode: Transfer Courses
Course Type: Transfer
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is intended for transfer credit for courses not offered at Rice. Permission of ECE Undergraduate Committee and review by faculty in related specialization area is required. ELEC 395 is for Junior level ECE Specialization course credit. Department Permission Required. Repeatable for Credit.

ELEC 403 - SCIENCE AND TECHNOLOGY BEHIND THE HEADLINES
Short Title: SCIENCE BEHIND THE HEADLINES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Our goal for this course is to increase and enhance our basic, fundamental understanding of scientific topics that are part of our current events and present concerns and challenges. We will use basic physics, chemistry, and biological principles to understand these topics at a more technical level than one can achieve by reading articles written by journalists. Our goal is to critically examine these currently popular technical topics to the depth at which a scientist or engineer can understand the basic principles and act as a science or technology advisor to government or political figures. Topics such as conventional and alternative energy, advanced military weapons, satellites, DNA forensics, AI, environmental toxins, and cybersecurity will be discussed. Graduate/Undergraduate Equivalency: ELEC 503. Mutually Exclusive: Cannot register for ELEC 403 if student has credit for ELEC 503.

ELEC 406 - LINEAR ALGEBRA FOR DATA SCIENCE
Short Title: LINEAR ALGEBRA FOR DS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Course Level: Undergraduate Upper-Level
Description: Algorithmic procedures for working with data have been developed by re-searchers from a wide range of areas. These include theoretical computer science (TCS), numerical linear algebra (NLA), statistics, applied mathematics, data analysis, machine learning, etc. As a consequence of the multi-disciplinarity of the area, researchers often fail to appreciate the underlying connections and the significance of contributions developed outside their own area. In this course, rather than focusing on technical details, we will focus on highlighting for a broad, basic linear-algebra-savvy audience, the simplicity and generality of some core linear algebraic ideas. In particular, we will focus on two fundamental and much used matrix problems which have been at the center of recent developments: (1) Least Squares approximation and (2) Low-Rank Matrix Approximation. A key tool for achieving this goal are randomized algorithms which originated in TCS. Graduate/Undergraduate Equivalency: ELEC 506.

ELEC 410 - SECURE AND CLOUD COMPUTING
Short Title: SECURE & CLOUD COMPUTING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 321
Description: What is "cloud computing?" How do we build cloud-scale systems and components that are secure against malicious attacks, and scale to millions of users? Many of today's services run inside the cloud – a set of geographically distributed data centers running heterogeneous software stacks. Cloud systems must scale across tens of thousands of machines, support millions of concurrent requests, and they must do so with high security guarantees. This course will start with the fundamentals of cloud computing, introduce key techniques in building scalable and secure systems and expose students to state-of-the-art research advances as well as emerging security threats and defenses in today's cloud systems. Cross-list: COMP 436. Graduate/Undergraduate Equivalency: ELEC 510. Mutually Exclusive: Cannot register for ELEC 410 if student has credit for ELEC 510.

ELEC 411 - MICROWAVE ENGINEERING
Short Title: MICROWAVE ENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics covered include transmission line, Smith Chart, scattering parameters, impedance matching, passive microwave circuits (power divider, coupler, 180° hybrid, filter), and antenna design fundamentals. Graduate/Undergraduate Equivalency: ELEC 517. Recommended Prerequisite(s): ELEC 262 or ELEC 305 or equivalent courses with the key concepts of Maxwell's Equations and Linear Algebra Mutually Exclusive: Cannot register for ELEC 411 if student has credit for ELEC 517.

ELEC 414 - WIRELESS INTEGRATED CIRCUITS AND SYSTEMS
Short Title: WIRELESS IC
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 305
Description: Topics covered include system architectures for modern wireless transceivers and transistor-level design considerations for circuit building blocks (low noise amplifier, mixer, power amplifier, etc.) in a wireless transceiver. Graduate/Undergraduate Equivalency: ELEC 514. Recommended Prerequisite(s): Equivalent Courses with the Key Concepts: • Transistor-level CMOS analog circuits (basic configurations, small-signal models, parasitic effects) • Frequency response of transistor-level CMOS circuits (pole/zero calculations) • Frequency response of simple passive networks (1st order and 2nd order RLC networks)• Noise analysis of transistor-level CMOS circuits (noise sources in CMOS transistors, input-referred voltage/current noise for CMOS transistor-level circuits)

ELEC 418 - PRINCIPLES OF BIOMEDICAL OPTICS AND ULTRASOUND
Short Title: BIOMEDICAL OPTICS & ULTRASOUND
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course introduces the science and engineering of biomedical applications based on optics and ultrasound. Students will explore how light travels in tissue, how ultrasound waves move through fluids and solids, and how these signals interact with the body. The course also covers computer modeling tools for light and the design of sensing devices using ultrasound. By the end, students will understand the foundations of optical and ultrasound technologies that support applications such as medical imaging, disease diagnosis, therapy guidance, and brain research. Graduate/Undergraduate Equivalency: ELEC 518. Recommended Prerequisite(s): Knowledge and understanding of differential equations Mutually Exclusive: Cannot register for ELEC 418 if student has credit for ELEC 518.

ELEC 420 - RISC-V SYSTEM-ON-CHIP DESIGN
Short Title: RISC-V SYSTEM-ON-CHIP DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course aims to provide a strong foundation for students to understand modern computer system architecture and to apply these insights and principles to future computer designs both in software and hardware. Graduate/Undergraduate Equivalency: ELEC 505. Recommended Prerequisite(s): COMP/ELEC 425/554 Mutually Exclusive: Cannot register for ELEC 420 if student has credit for ELEC 505.

ELEC 421 - OPERATING SYSTEMS AND CONCURRENT PROGRAMMING
Short Title: OP SYS/CONCURRENT PROGRAMMING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 215 and COMP 321
Description: Introduction to the design, construction, and analysis of concurrent programs with an emphasis on operating systems, including filing systems, schedulers, and memory allocators. Specific attention is devoted to process synchronization and communication within concurrent programs. Cross-list: COMP 421. Graduate/Undergraduate Equivalency: ELEC 552. Mutually Exclusive: Cannot register for ELEC 421 if student has credit for ELEC 552.
Course URL: www.clear.rice.edu/comp421/ (http://www.clear.rice.edu/comp421/)

ELEC 422 - VLSI SYSTEMS DESIGN
Short Title: VLSI SYSTEMS DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 326 or COMP 326
Description: A study of VLSI technology and design. MOS devices, Characteristics and fabrication. Logic design and implementation. VLSI design methodology, circuit simulation and verification. Graduate/Undergraduate Equivalency: ELEC 527. Mutually Exclusive: Cannot register for ELEC 422 if student has credit for ELEC 527.

ELEC 423 - DIGITAL INTEGRATED CIRCUITS
Short Title: DIGITAL INTEGRATED CIRCUITS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 220 and ELEC 242 and (ELEC 326 or COMP 326)
Description: This course introduces students to the analysis and design of digital integrated circuits. We look at how CMOS devices are fabricated and how they operate physically, as well as how to design high-performance and low-power circuits. Various types of memory devices and designs are also covered in the course. Recommended Prerequisite(s): ELEC 305 or ELEC 261.

ELEC 424 - MOBILE AND EMBEDDED SYSTEM DESIGN AND APPLICATION
Short Title: MOBILE & EMBEDDED SYSTEM
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 220 or COMP 222
Description: ELEC 424 introduces mobile and embedded system design and applications to undergraduate students and provides them hands-on design experience. It consists of three interlearning parts: lectures, student project, and student presentations. Cross-list: COMP 424. Graduate/Undergraduate Equivalency: ELEC 553. Mutually Exclusive: Cannot register for ELEC 424 if student has credit for ELEC 553.

ELEC 425 - COMPUTER SYSTEMS ARCHITECTURE
Short Title: COMPUTER SYSTEMS ARCHITECTURE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 326 or COMP 326
Description: Evolution of key architecture concepts found in advanced uniprocessor systems. Fundamental and advanced pipelining techniques and associated issues for improving processor performance. Illustrated with RISC processors such as the ARM processor. Examine several metrics for processor performance, such as Amdahl's law. Key concepts of data and program memory systems found in modern systems with memory hierarchies and cashes. Perform experiments in cache performance analysis. Influence of technology trends, such as Moore's law, on processor implementation Approaches for exploiting instruction level parallelism, such as VLIW. Introduction to parallel and multicore architectures. Introduction to processor architectures targeted for imbedded applications. Cross-list: COMP 425. Graduate/Undergraduate Equivalency: ELEC 554. Mutually Exclusive: Cannot register for ELEC 425 if student has credit for ELEC 554.

ELEC 426 - ADVANCED DIGITAL INTEGRATED CIRCUITS DESIGN
Short Title: ADV DIGITAL IC DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 305 and (ELEC 326 or COMP 326)
Description: The course addresses advanced issues in custom digital IC design. Topics range from physical-level analysis and modeling of new devices, interconnect, and power supply, to circuit-level design techniques for low power and high performance, to application-oriented digital circuits/systems for security and machine learning. Graduate/Undergraduate Equivalency: ELEC 521. Recommended Prerequisite(s): ELEC 342, 422 and 423.

ELEC 428 - PROCESSOR MICROARCHITECTURE DESIGN AND IMPLEMENTATION
Short Title: PROCESSOR MICROARCHITECTURE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 326
Description: The course covers the design and implementation of micro-architectural components of modern CPU and memory systems. Topics covered include static and dynamic pipelines, out-of-order execution, instruction speculation, reorder buffers, static and dynamic branch prediction, multi-threaded, VLIW, and vector processors, cache memory organization and implementation, and an introduction to multiprocessor cache coherence and virtual memory. The course will require Verilog implementations of several micro-architectural components and their integration into a working CPU. Recommended Prerequisite(s): ELEC 425

ELEC 429 - INTRODUCTION TO COMPUTER NETWORKS
Short Title: INTRO TO COMPUTER NETWORKS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 321
Description: Network architectures, algorithms, and protocols. Local- and Wide-area networking. Intra- and inter-domain routing. Transmission reliability. Flow and congestion control. TCP/IP. Multicast. Quality of Service. Network Security - Networked applications. Cross-list: COMP 429. Graduate/Undergraduate Equivalency: ELEC 556. Mutually Exclusive: Cannot register for ELEC 429 if student has credit for ELEC 556.
Course URL: www.clear.rice.edu/comp429/ (http://www.clear.rice.edu/comp429/)

ELEC 430 - MODERN COMMUNICATION THEORY AND PRACTICE
Short Title: MODERN COMM. THEORY & PRACTICE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (ELEC 242 or ELEC 301) and ELEC 303
Description: This is an upper-level course in digital communications, which is designed to prepare students for engineering work in high-tech industries and for graduate work in communications, signal processing, and computer systems. The course covers basic concepts and useful tools for design and performance analysis of transmitters and receivers in the physical layer of a communication system, including multiple antenna MIMO systems. A hands-on laboratory using a state-of-the-art radio testbed illustrates course concepts. Mutually Exclusive: Cannot register for ELEC 430 if student has credit for ELEC 551. Graduate/Undergraduate Equivalency: ELEC 551. Mutually Exclusive: Cannot register for ELEC 430 if student has credit for ELEC 551.

ELEC 431 - DIGITAL SIGNAL PROCESSING
Short Title: DIGITAL SIGNAL PROCESSING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 242 or ELEC 301
Description: Methods for analysis of discrete-time signals and design of discrete-time systems including topics of: discrete-time linear systems, difference equations, z-transforms, discrete convolution, stability, discrete-time Fourier transforms, analog-to-digital and digital-to-analog conversion, digital filter design, discrete Fourier transforms, fast Fourier transforms, multi-rate signal processing, filter banks, and spectral analysis. Graduate/Undergraduate Equivalency: ELEC 558. Mutually Exclusive: Cannot register for ELEC 431 if student has credit for ELEC 558.

ELEC 434 - ADVANCED HIGH-SPEED SYSTEM DESIGN
Short Title: ADV H-S SYSTEM DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 305 and ELEC 244
Description: This course covers practical aspects of high-speed system design, highlights system design and simulation challenges, and demonstrates common pitfalls and how to prevent them. In this course, students will learn how to design, do gigahertz speed PCB layout, simulate (spice and Hyperlynx), and apply good design practices to minimize both component and system noise and to ensure system design success. Graduate/Undergraduate Equivalency: ELEC 543. Mutually Exclusive: Cannot register for ELEC 434 if student has credit for ELEC 543.

ELEC 435 - NEURAL INTERFACE ENGINEERING LABORATORY
Short Title: NEURAL INTERFACE ENG LAB
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 140 or BIOE 391
Description: This course is designed to provide students with hands-on experience with the techniques and tools of neural engineering towards health, rehabilitation, and assistive technology applications. During the course, students will develop a deeper understanding of the underlying principles and phenomena of engineered systems interacting with the nervous system. The course will also expose students to hardware, software, and techniques that may be useful in their future coursework and careers. Students will work individually and in teams through a series of experiments. Students will also learn and use key concepts in designing experiments and testing neural interface systems, which they will use to propose and conduct a final project of their own design. Graduate/Undergraduate Equivalency: ELEC 532. Recommended Prerequisite(s): ELEC 380 Mutually Exclusive: Cannot register for ELEC 435 if student has credit for ELEC 532.

ELEC 436 - FUNDAMENTALS OF CONTROL SYSTEMS
Short Title: FUNDAMENTALS OF CONTROL SYST
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CAAM 335 or CMOR 302 and MECH 341 or MECH 499) or (MATH 355 and MECH 343 or MECH 499) or (CAAM 335 or CMOR 302 and ELEC 242 and ELEC 244) or (MATH 355 and ELEC 242 and ELEC 244)
Description: Linear systems and the fundamental principles of classical feedback control, state variable analysis of linear dynamic systems, stability of linear control systems, time-domain analysis and control of linear systems, root-locus analysis and design and pole-zero synthesis, frequency domain techniques for the analysis and design of control systems. Required for mechanical engineering majors in B.S. program. Cross-list: MECH 420.

ELEC 437 - INTRODUCTION TO COMMUNICATION NETWORKS
Short Title: INTRO TO COMMUNICATION NETWORK
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 303
Description: Introduction to design and analysis of communication networks. Topics include wireless networks, media access, routing traffic modeling, congestion control, and scheduling. Graduate/Undergraduate Equivalency: ELEC 539. Mutually Exclusive: Cannot register for ELEC 437 if student has credit for ELEC 539.

ELEC 438 - BIOMEDICAL OPTICAL IMAGING AND APPLICATIONS
Short Title: BIOMEDICAL OPTICAL IMAG & APPL
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): PHYS 102 or PHYS 112 or PHYS 126
Description: This course first covers established optical imaging technologies and their biomedical applications. Topics include sensing optical properties and spectroscopy, ballistic imaging methods (confocal, two-photon, super-resolution, etc.), optical coherence tomography, diffuse optical tomography, photoacoustic tomography, and optical time reversal (wavefront shaping/engineering). Graduate/Undergraduate Equivalency: ELEC 530. Mutually Exclusive: Cannot register for ELEC 438 if student has credit for ELEC 530.

ELEC 439 - DATA SCIENCE AND DYNAMICAL SYSTEMS
Short Title: DATA AND SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: In many applications one is faced with the task of simulating or controlling complex dynamical systems. Such applications include for instance, weather prediction, air quality management, VLSI chip design, molecular dynamics, active noise reduction, chemical reactors, etc. In all these cases complexity manifests itself as the number of first order differential equations which arise. Model (order) reduction (MOR) seeks to replace a large-scale system described in terms of differential or difference equations by a system of much lower dimension that has nearly the same response characteristics. The ensuing methods have been an indispensable tool for speeding up the simulations arising in various engineering applications involving large-scale dynamical systems. In this course we will develop the underlying approximation theory paying particular attention to its data-driven aspects. Graduate/Undergraduate Equivalency: ELEC 519. Recommended Prerequisite(s): ELEC 301 OR MATH 355 OR CAAM 335 Mutually Exclusive: Cannot register for ELEC 439 if student has credit for ELEC 519.

ELEC 440 - ARTIFICIAL INTELLIGENCE
Short Title: ARTIFICIAL INTELLIGENCE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 212 or MATH 232) and (ELEC 303 or STAT 310 or ECON 307 or STAT 311 or STAT 312 or STAT 315 or DSCI 301) and (CAAM 334 or CAAM 335 or CMOR 302 or CMOR 303 or MATH 354 or MATH 355) and (COMP 382 or COMP 582) and (COMP 310 or COMP 318)
Description: This is a foundational course in artificial intelligence, the discipline of designing intelligent agents. The course will cover the design and analysis of agents that do the right thing in the face of limited information and computational resources. The course revolves around two main questions: how agents decide what to do, and how they learn from experience. Tools from computer science, probability theory, and game theory will be used. Interesting examples of intelligent agents will be covered, including poker playing programs, bots for various games (e.g. WoW), DS1 -- the spacecraft that performed an autonomous flyby of Comet Borrely in 2001, Stanley -- the Stanford robot car that won the Darpa Grand Challenge, Google Maps and how it calculates driving directions, face and handwriting recognizers, Fedex package delivery planners, airline fare prediction sites, and fraud detectors in financial transactions. Cross-list: COMP 440. Graduate/Undergraduate Equivalency: ELEC 557. Mutually Exclusive: Cannot register for ELEC 440 if student has credit for ELEC 557.
Course URL: www.owlnet.rice.edu/~comp440 (http://www.owlnet.rice.edu/~comp440/)

ELEC 442 - INTRODUCTION TO ANALOG INTEGRATED CIRCUITS
Short Title: ANALOG INTEGRATED CIRCUITS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 242
Description: There has been growing interest in analog computing in both academia and industry in the era of artificial intelligence. This course provides a comprehensive introduction to various aspects of modern analog integrated circuits. Students will learn how to 1) analyze, simulate and design a complementary metal oxide semiconductor (CMOS) analog integrated circuit, 2) analyze and simulate elementary transistor stages, current mirrors, supply- and temperature-independent bias and reference circuits, and 3) explore performance evaluation using computer-aided design tools. Graduate/Undergraduate Equivalency: ELEC 516. Mutually Exclusive: Cannot register for ELEC 442 if student has credit for ELEC 516.

ELEC 445 - INTRODUCTION TO DIGITAL IMAGE AND VIDEO PROCESSING
Short Title: DIGITAL IMAGE & VIDEO PROC.
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 242 or ELEC 301
Description: This course covers theory and tools for representing and processing digital images and video. Topics include: multi-dimensional sampling, transforms, and filtering; human visual perception; visual scanning and display; tomographic reconstruction; image and video coding theory and standards; video streaming; and, image restoration. Recommended Prerequisite(s): ELEC 431

ELEC 447 - INTRODUCTION TO COMPUTER VISION
Short Title: INTRO TO COMPUTER VISION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 242 or ELEC 301 or ELEC 475 or COMP 330
Description: An introduction to the basic concepts, algorithms and applications in computer vision. Topics include: image processing pipelines, low-level vision/image processing methods such as filtering and edge detection, mid-level vision topics such as segmentation and feature detection, and high-level vision tasks such as object recognition and face recognition with neural networks. The course will involve programming and implementing basic computer vision algorithms in Python. Cross-list: COMP 447. Graduate/Undergraduate Equivalency: ELEC 546. Mutually Exclusive: Cannot register for ELEC 447 if student has credit for ELEC 345/ELEC 546.

ELEC 448 - 3D VISION: FROM AUTONOMOUS CARS TO THE METAVERSE
Short Title: ADVS IN 3D SENSING & VIS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The goals of the course are to study basic concepts, and algorithms in 3D computer vision and their integration into various applications including autonomous navigation and augmented reality systems. Topics include: cameras, camera models, stereo, structured light, LIDAR, time-of-flight, case studies on autonomous driving, augmented reality and 3D avatars. The course will involve programming and implementing basic computer vision algorithms in Matlab/Python. Students will learn the fundamentals behind various 3D sensors and 3D computer vision algorithms and how the different performance capabilities make them relevant for integration into various application domains including autonomous navigation, augmented reality and 3D avatars. Graduate/Undergraduate Equivalency: ELEC 541. Recommended Prerequisite(s): Prior knowledge of undergraduate-level linear algebra is a plus, but the course is self-contained. Mutually Exclusive: Cannot register for ELEC 448 if student has credit for ELEC 541.

ELEC 450 - ALGORITHMIC AND AI-DRIVEN ROBOTICS
Short Title: ALGORITHMIC AND AI-DRIVEN ROBO
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): COMP 321 and COMP 215
Description: Robots have fascinated people for generations. Today, robots are built for applications as diverse as exploring remote planets, de-mining war zones, cleaning toxic waste, assembling cars, inspecting pipes in industrial plants and mowing lawns. Robots are also interacting with humans in a variety of ways: robots are museum guides, robots assist surgeon sin life threatening operations, and robotic cars can drive us around. The field of robotics studies not only the design of new mechanisms but also the development of artificial intelligence frameworks to make these mechanism useful in the physical world, integrating computer science, engineering, mathematics and more recently biology and sociology, in a unique way. This class will present fundamental algorithmic advances that enable today's robots to move in real environments and plan their actions. It will also explore fundamentals of the field of Artificial Intelligence through the prism of robotics. The class involves a significant programming project. Cross-list: COMP 450, MECH 450. Graduate/Undergraduate Equivalency: ELEC 550. Mutually Exclusive: Cannot register for ELEC 450 if student has credit for ELEC 550.

ELEC 459 - IMAGE AND VIDEO COMPRESSION ALGORITHMS AND STANDARDS
Short Title: IMAGE AND VIDEO COMPRESSION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to the basic theory of image and video coding and comprehensive coverage of modern techniques used in current video coding standards and in advanced standards currently in development. Course projects include hands-on experience with actual reference software used in video coding standard development activities. Coverage includes protocols used for video streaming. Graduate/Undergraduate Equivalency: ELEC 559. Recommended Prerequisite(s): Undergraduate background in Electrical Engineering signal & systems Mutually Exclusive: Cannot register for ELEC 459 if student has credit for ELEC 559.

ELEC 460 - PHYSICS OF SENSOR MATERIALS AND NANOSENSOR TECHNOLOGY
Short Title: PHYSICS OF SENSORS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 261 and ELEC 305
Description: Topics covered include MEMS, MOEMS, and NEMS systems along with special materials such as liquid crystals, piezoelectrics, memory metal, and topological insulators. Graduate/Undergraduate Equivalency: ELEC 560. Mutually Exclusive: Cannot register for ELEC 460 if student has credit for ELEC 560.

ELEC 461 - QUANTUM MECHANICS AND REAL-WORLD APPLICATIONS
Short Title: QUANTUM MECH AND APPLICATIONS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 361
Description: This course will provide a basic understanding of the principles of applied quantum mechanics, with examples of real-world applications. A foundation is laid for advanced topics in the areas of lasers, microwave and optical detectors, nanoelectronics, quantum computers, quantum sensors, etc. Senior undergraduate students and junior graduate students in the areas of quantum engineering, nanotechnology, photonics and electronics, especially experimentalists, will find this course useful. Graduate/Undergraduate Equivalency: ELEC 580. Recommended Prerequisite(s): Basic knowledge of: (1) calculus, linear algebra, complex number, vector operation, differential equations; (2) classical mechanics; (3) classical electromagnetics; (4) atomic structure, chemical boding; (5) basic quantum mechanics, including static Schrodinger equation. Mutually Exclusive: Cannot register for ELEC 461 if student has credit for ELEC 580.

ELEC 462 - OPTOELECTRONIC DEVICES
Short Title: OPTOELECTRONIC DEVICES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 305
Description: This course provides an introduction to the fundamental principles of semiconductor optoelectronic devices. After reviewing the basic elements of quantum mechanics of electrons and photons, light-matter interaction (including laser oscillations), and semiconductor physics (band structure, heterostructures and alloys, optical processes), we will study the details of modern semiconductor devices for the generation, detection, and modulation of light. Graduate/Undergraduate Equivalency: ELEC 562. Mutually Exclusive: Cannot register for ELEC 462 if student has credit for ELEC 562.
Course URL: www.ece.rice.edu/~kono/ELEC462.html (http://www.ece.rice.edu/~kono/ELEC462.html)

ELEC 468 - INTRODUCTION TO QUANTUM COMPUTING WITH QISKIT
Short Title: QUANTUM COMPUTING WITH QISKIT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Quantum information science and technology have been rapidly developed amid the global quantum research effort on quantum computing, communication, simulation and sensing. Significant progress has been made in quantum computing, demonstrating unprecedented quantum advantage over classical computers on specific computation tasks. This course will cover the engineering and mathematics aspects of quantum computing and algorithms, as well as discuss software implementation using Qiskit on Python platform and hardware implementation using real IBM quantum computers. Graduate/Undergraduate Equivalency: ELEC 568. Recommended Prerequisite(s): Linear Algebra Mutually Exclusive: Cannot register for ELEC 468 if student has credit for ELEC 568.

ELEC 475 - LEARNING FROM SENSOR DATA
Short Title: LEARNING FROM SENSOR DATA
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 303 or DSCI 301 or STAT 310 or STAT 311
Description: Basic information theoretic metrics and probabilistic machine learning tools for signals, images, and other data acquired from sensors, including graphical models, density estimation, principal components analysis, support vector machines, and source separation. Graduate/Undergraduate Equivalency: ELEC 575. Mutually Exclusive: Cannot register for ELEC 475 if student has credit for ELEC 575. Graduate/Undergraduate Equivalency: ELEC 575. Mutually Exclusive: Cannot register for ELEC 475 if student has credit for ELEC 575.

ELEC 477 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Laboratory, Lecture, Seminar, Lecture/Laboratory, Independent Study
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

ELEC 478 - INTRODUCTION TO MACHINE LEARNING
Short Title: INTRO TO MACHINE LEARNING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (STAT 405 or CAAM 210 or CMOR 220 or COMP 140 or DSCI 101) and (CAAM 334 or CMOR 303 or CAAM 335 or CMOR 302 or MATH 355 or MATH 354) and (ELEC 303 or DSCI 301 or STAT 310 or STAT 311)
Description: This course is an advanced introduction to concepts, methods, best practices, and theoretical foundations of machine learning. Topics covered include regression, classification, regularization, kernels, clustering, dimension reduction, decision trees, ensemble learning, and neural networks. Graduate/Undergraduate Equivalency: ELEC 578. Mutually Exclusive: Cannot register for ELEC 478 if student has credit for COMP 540/DSCI 303/ELEC 578/STAT 413/STAT 613.

ELEC 481 - ELECTROMAGNETISM AND THE BRAIN
Short Title: ELECTROMAGNETISM AND THE BRAIN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Human brain activity is a specific form bioelectromagnetism, which is the multi-disciplinary study of the electromagnetic (EM) phenomena that arise in biological tissues. This class studies the considerable variety of “brain signals” and the generation of their corresponding EM fields that can be detected with electric and magnetic sensors. What is the intrinsic information of each signal type and in what context are those useful? Topics include EM, biophysics, spectral analysis, forward modeling, reciprocity, source localization, and the electrode/insulator design. Your final team project will build a finite element model (FEM) of brain activity and/or biophysical model and analyze those signals in a specific application. Graduate/Undergraduate Equivalency: ELEC 583. Recommended Prerequisite(s): Introductory courses in physics, e.g. Physics 102 or 112 or 126, and time-series signal analysis, e.g., ELEC 242 or NEUR 383. Mutually Exclusive: Cannot register for ELEC 481 if student has credit for ELEC 583.

ELEC 482 - ARTIFICIAL INTELLIGENCE FOR HEALTH
Short Title: AI FOR HEALTH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 378 or DSCI 303 or COMP 341
Description: This course introduces the latest artificial intelligence technology for healthcare. The class materials focus on methods, systems, applications, challenges, and ethical considerations. Through lectures, discussions, case studies, assignments, and hands-on projects, students will gain a comprehensive understanding of AI technologies in healthcare, from medical imaging and clinical decision support to population health management and drug discovery. Additionally, the course will include discussions about ethical, legal, and social implications of AI and its potential applications in healthcare. Graduate/Undergraduate Equivalency: ELEC 509. Mutually Exclusive: Cannot register for ELEC 482 if student has credit for ELEC 509.

ELEC 483 - MACHINE LEARNING AND SIGNAL PROCESSING FOR NEURO ENGINEERING
Short Title: NEURAL SIGNAL PROCESSING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 220 or COMP 140
Description: This course covers signal processing and machine learning approaches for modern neuroscience data. Topics include latent variable models, point processes, dimensionality reduction, dynamical systems, and spectral analysis. Neuroscience applications include modeling neural firing rates, spike sorting, encoding, decoding, and electrical stimulation. Students will be introduced to public toolboxes that implement these methods. Cross-list: ELEC 548, BIOE 548. Graduate/Undergraduate Equivalency: ELEC 548. Recommended Prerequisite(s): (MATH 354 OR MATH 355 OR CMOR 302 OR CMOR 303) AND (ELEC 303 OR STAT 305 OR STAT 310 OR ECON 307) Mutually Exclusive: Cannot register for ELEC 483 if student has credit for ELEC 548.

ELEC 487 - IMAGING OPTICS
Short Title: IMAGING OPTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): PHYS 102 or PHYS 112 or PHYS 126
Description: The course covers the fundamental properties of light propagation and interaction with matter under the approximations of geometrical optics and scalar wave optics, as well as the fundamentals of optical microscopy. The course emphasizes a system approach to the analysis and design of optical systems from a user and an engineering perspective, focusing on the physical intuition and underlying mathematical tools, and application of the physical concepts to topical engineering domains such as a selection of microscopy techniques. Students will have direct hands-on experience with optics and optical imaging systems in the classroom. Graduate/Undergraduate Equivalency: ELEC 582. Mutually Exclusive: Cannot register for ELEC 487 if student has credit for ELEC 582.

ELEC 488 - THEORETICAL NEUROSCIENCE: FROM CELLS TO LEARNING SYSTEMS
Short Title: THEORETICAL NEUROSCIENCE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 102 or MATH 106) and (MATH 211 or MATH 220 or CMOR 304)
Description: This course presents the theoretical foundations of cellular and systems neuroscience from a quantitative perspective, integrating mathematical modeling, computational tools, and data analysis. Students will develop and apply differential equations, probabilistic models, and reverse correlation techniques to analyze neural activity and synaptic interactions. The course combines traditional lectures with student-led presentations in a seminar-style format. Coursework includes problem sets, coding-based assignments, and group projects. MATLAB or Python proficiency is strongly recommended. Cross-list: CMOR 415, NEUR 415. Graduate/Undergraduate Equivalency: ELEC 588. Recommended Prerequisite(s): This course requires coding in MATLAB or Python. As such, COMP 140, CMOR 220 or some equivalent coding experience is highly recommended. Mutually Exclusive: Cannot register for ELEC 488 if student has credit for ELEC 588.

ELEC 489 - NEURAL COMPUTATION
Short Title: NEURAL COMPUTATION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: How does the brain work? Understanding the brain requires sophisticated theories to make sense of the collective actions of billions of neurons and trillions of synapses. Word theories are not enough; we need mathematical theories. The goal of this course is to provide an introduction to the mathematical theories of learning and computation by neural systems. These theories use concepts from dynamical systems (attractors, oscillations, chaos) and concepts from statistics (information, uncertainty, inference) to relate the dynamics and functions of neural networks. We will apply these theories to sensory computation, learning and memory, and motor control. Students will learn to formalize and mathematically answer questions about neural computations, including "what does a network compute?", "how does it compute?", and "why does it compute that way?" Prerequisites: knowledge of calculus, linear algebra, and probability and statistics. Cross-list: CMOR 416, NEUR 416. Graduate/Undergraduate Equivalency: ELEC 589. Mutually Exclusive: Cannot register for ELEC 489 if student has credit for ELEC 589.

ELEC 490 - UNDERGRADUATE ELECTRICAL ENGINEERING RESEARCH PROJECTS
Short Title: UG ELEC ENG'G RES PROJECTS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Theoretical and experimental investigations under staff direction. A research project plan should be prepared and approved by the faculty member advising the project. Information about ELEC 490 project plans is available on the ECE Web site on the Academics section under ECE forms. May be repeated for a total of 6 credit hours for undergraduates. Instructor Permission Required. Repeatable for Credit.

ELEC 491 - UNDERGRADUATE ELECTRICAL ENGINEERING RESEARCH PROJECTS-VERTICALLY INTEGRATED PROJECTS
Short Title: UG ELEC ENG'G RESEARCH VIP
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Vertically Integrated Projects (VIP) teams include students from multiple years working on one larger, multi-year project defined by the instructor. Students participating in VIP for 3 or more semesters may be eligible for the Distinction in Research and Creative Work graduation award. Instructor Permission Required. Graduate/Undergraduate Equivalency: ELEC 591. Repeatable for Credit.

ELEC 494 - SENIOR DESIGN I
Short Title: SENIOR DESIGN I
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Senior Design is a year-long course required of all BSEE-degree students. In order to fulfill the BSEE degree requirements, students must register for ELEC 494 and ELEC 496 for both the fall and spring semesters of the same academic year. The course is taught in conjunction with the Senior Design courses in BioEngineering and in Mechanical Engineering and Materials Science. Teams of students will design, construct, and document a prototype system to meet specifications determined by the team and the instructor. Senior design projects are the culmination of the Rice engineering experience. Cross-departmental projects are allowed and encouraged, and extensive use will be made of the Oshman Engineering Design Kitchen. Many projects will involve advisors from industrial affiliates. Throughout the year there will be several opportunities for presentations on the project. Top projects will be eligible for several awards from within Rice and outside the university, including some nation-wide competitions. Instructor Permission Required. Repeatable for Credit.

ELEC 495 - TRANSFER CREDIT - SENIOR
Short Title: TRANSFER CREDIT - SENIOR
Department: Electrical & Computer Eng.
Grade Mode: Transfer Courses
Course Type: Transfer
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is intended for transfer credit for courses not offered at Rice. Permission of ECE Undergraduate Committee and review by faculty in related specialization area is required. ELEC 495 is for Senior level ECE Specialization course credit. Department Permission Required. Repeatable for Credit.

ELEC 496 - SENIOR DESIGN II
Short Title: SENIOR DESIGN II
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 494
Description: ELEC 496 is the second part of a year-long capstone design course required of all BSECE students. In order to fulfill the BSECE degree requirements, students must complete ELEC 494 (SENIOR DESIGN I) in fall semester and ELEC 496 (SENIOR DESIGN II) in spring semester of the same academic year. The course is taught in conjunction with the Senior Design courses in BioEngineering, Mechanical Engineering, Materials Science and NanoEngineering, and Global Health Technologies. Teams of students will design, construct, and document a prototype system to meet specifications determined by the team and the instructor. Senior design projects are the culmination of the Rice engineering experience. Cross-departmental projects are allowed and encouraged, and extensive use will be made of the Oshman Engineering Design Kitchen. Many projects will involve advisors from industrial affiliates. Throughout the year, there will be several opportunities for presentations on the project. All teams will present their projects at Rice's Engineering Design Showcase. Additionally, teams are required to enter at least one national or international competition or submit a publication for peer review in an appropriate conference or journal. Top projects will be eligible for several awards from within Rice and outside the university. Instructor Permission Required.

ELEC 498 - INTRODUCTION TO ROBOTICS
Short Title: INTRODUCTION TO ROBOTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): MATH 354 or MATH 355 or CAAM 335 or CMOR 302
Description: The course will provide the student with a mathematical introduction to many of the key ideas used in today's intelligent robot systems. The focus of the course is on the analysis and control of manipulators. The course will also give an overview of common approaches to building intelligent robot systems. Cross-list: COMP 498, MECH 498. Graduate/Undergraduate Equivalency: ELEC 598. Recommended Prerequisite(s): MECH 211 or CEVE 211 or MECH 310 Mutually Exclusive: Cannot register for ELEC 498 if student has credit for ELEC 598.

ELEC 502 - NEURAL MACHINE LEARNING I
Short Title: NEURAL MACHINE LEARNING I
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Review of major neural machine learning (Artificial Neural Network) paradigms. Analytical discussion of supervised and unsupervised neural learning algorithms and their relation to information theoretical methods. Practical applications to data analysis such as pattern recognition, clustering, classification, function approximation/ regression, non-linear PCA, projection pursuit, independent component analysis, with lots of examples from image and digital processings. Details are posted at www.ece.rice.edu/~erzsebet/ANNcourse.html. Cross-list: COMP 502, STAT 502. Recommended Prerequisite(s): ELEC 430 and ELEC 431 or equivalent or permission of instructor.
Course URL: www.ece.rice.edu/~erzsebet/ANNcourse.html (http://www.ece.rice.edu/~erzsebet/ANNcourse.html)

ELEC 503 - SCIENCE AND TECHNOLOGY BEHIND THE HEADLINES
Short Title: SCIENCE BEHIND THE HEADLINES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Our goal for this course is to increase and enhance our basic, fundamental understanding of scientific topics that are part of our current events and present concerns and challenges. We will use basic physics, chemistry, and biological principles to understand these topics at a more technical level than one can achieve by reading articles written by journalists. Our goal is to critically examine these currently popular technical topics to the depth at which a scientist or engineer can understand the basic principles and act as a science or technology advisor to government or political figures. Topics such as conventional and alternative energy, advanced military weapons, satellites, DNA forensics, AI, environmental toxins, and cybersecurity will be discussed. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 403. Mutually Exclusive: Cannot register for ELEC 503 if student has credit for ELEC 403.

ELEC 504 - PUBLISHING YOUR FIRST SCIENTIFIC RESEARCH PAPER
Short Title: PUBLISHING YOUR FIRST PAPER
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Completing the last 10% of your first research paper is one of the biggest hurdles for many PhD students. You have collected most of your data. You have a rough figure outline. You might even have a first draft of your manuscript. But getting from data to manuscript to accepted paper requires new skills. This course is designed for students with publication-quality data, and will address: How to frame the motivation, knowledge gap, and conclusion statement? How to edit for a particular journal target? How to arrange the results to support the strongest hypothesis? How to select appropriate reviewers? How to write (and rewrite) an abstract? How to write a cover letter? And finally, how to respond to reviewers and GET YOUR PAPER PUBLISHED? Students with publication-ready data will work through all of these issues together within this course, led by an experienced journal editor. Instructor Permission Required. Cross-list: CHBE 504, CHEM 504.

ELEC 505 - RISC-V SYSTEM-ON-CHIP DESIGN
Short Title: RISC-V SYSTEM-ON-CHIP DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course aims to provide a strong foundation for students to understand modern computer system architecture and to apply these insights and principles to future computer designs both in software and hardware. Graduate/Undergraduate Equivalency: ELEC 420. Recommended Prerequisite(s): COMP/ELEC 425/554 Mutually Exclusive: Cannot register for ELEC 505 if student has credit for ELEC 420.

ELEC 506 - LINEAR ALGEBRA FOR DATA SCIENCE
Short Title: LINEAR ALGEBRA FOR DS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Algorithmic procedures for working with data have been developed by re-searchers from a wide range of areas. These include theoretical computer science (TCS), numerical linear algebra (NLA), statistics, applied mathematics, data analysis, machine learning, etc. As a consequence of the multi-disciplinarity of the area, researchers often fail to appreciate the underlying connections and the significance of contributions developed outside their own area. In this course, rather than focusing on technical details, we will focus on highlighting for a broad, basic linear-algebra-savvy audience, the simplicity and generality of some core linear algebraic ideas. In particular, we will focus on two fundamental and much used matrix problems which have been at the center of recent developments: (1) Least Squares approximation and (2) Low-Rank Matrix Approximation. A key tool for achieving this goal are randomized algorithms which originated in TCS. Graduate/Undergraduate Equivalency: ELEC 406.

ELEC 507 - NON LINEAR DYNAMIC SYSTEMS ANALYSIS
Short Title: NONLINEAR DYNAMIC SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Analytical methods for the study of nonlinear systems are introduced, including singular point and phase plane analysis, the describing function technique, Lyapunov and Lagrangian state functions, stability analysis, bifurcation analysis, and chaotic behavior in nonlinear dynamic systems. As a substrate for the study of nonlinear systems, numerical analysis of ordinary and partial differential equations, boundary value problems, simulation methods, parameter estimation and sensitivity analysis methods are also included.

ELEC 508 - NONLINEAR SYSTEMS: ANALYSIS AND CONTROL
Short Title: NONLINEAR SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Mathematical background and fundamental properties of nonlinear systems: Vector norms, matrix norms, matrix measures, existence and uniqueness of solutions of ordinary differential equations. Linearization, second order systems, periodic solutions, approximate methods. Lyapunov stability: Stability definitions, Lyapunov's direct method, invariance theory, stability of linear systems, Lyapunov's linearization method, converse theorems. Selected topics in nonlinear systems analysis and nonlinear control from: Input/Output stability: Small gain theorem, passivity theorem. Perturbation theory, averaging, and singular perturbations Feedback linearization control. Other methods in the control of nonlinear systems such as backstepping, sliding mode and other Lyapunov-based design methods. Advanced nonlinear and adaptive robot control. Cross-list: CMOR 508, MECH 508.

ELEC 509 - ARTIFICIAL INTELLIGENCE FOR HEALTH
Short Title: AI FOR HEALTH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces the latest artificial intelligence technology for healthcare. The class materials focus on methods, systems, applications, challenges, and ethical considerations. Through paper reading, lectures, discussions, case studies, assignments, and hands-on projects, students will gain a comprehensive understanding of AI technologies in healthcare, from medical imaging and clinical decision support to digital twins and intervention development. Additionally, the course will include discussions about ethical and social implications of AI and its potential applications in healthcare. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 482. Mutually Exclusive: Cannot register for ELEC 509 if student has credit for ELEC 482.

ELEC 510 - SECURE AND CLOUD COMPUTING
Short Title: SECURE & CLOUD COMPUTING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: What is "cloud computing?" How do we build cloud-scale systems and components that are secure against malicious attacks, and scale to millions of users? Many of today's services run inside the cloud – a set of geographically distributed data centers running heterogeneous software stacks. Cloud systems must scale across tens of thousands of machines, support millions of concurrent requests, and they must do so with high security guarantees. This course will start with the fundamentals of cloud computing, introduce key techniques in building scalable and secure systems and expose students to state-of-the-art research advances as well as emerging security threats and defenses in today's cloud systems. Cross-list: COMP 536. Graduate/Undergraduate Equivalency: ELEC 410. Mutually Exclusive: Cannot register for ELEC 510 if student has credit for ELEC 410.

ELEC 511 - DESIGN AND ANALYSIS OF SECURE EMBEDDED SYSTEMS FOR IOT ERA
Short Title: SECURE EMBEDDED SYS FOR IOT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course emphasizes the security of small embedded devices that are central to the Internet of Things (IoT) Era. We discuss the practical security attacks, challenges, constraints, and opportunities that arise in the IoT domain. Covered topics include security engineering, real world attacks, practical and side channel attacks, and hands-on lab/projects. Cross-list: COMP 508. Repeatable for Credit.

ELEC 512 - GRADUATE DESIGN AND ANALYSIS OF ALGORITHMS
Short Title: GR DESGN ANALY OF ALGORITHMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Methods for designing and analyzing computer algorithms and data structures. The focus of this course will be on the theoretical and mathematical aspects of algorithms and data structures. Cross-list: COMP 582. Recommended Prerequisite(s): STAT 310 or ECON 307 or STAT 331 or ELEC 331 or ELEC 303 or STAT 312

ELEC 513 - COMPLEXITY IN MODERN SYSTEMS
Short Title: COMPLEXITY IN MODERN SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A modern computer is a system with enormous complexity in both software and hardware. The course presents the principles for managing such complexity using examples from modern computing systems. It covers emergent issues from system complexity such as energy efficiency, bug finding, and heterogeneous hardware. It also covers designing experiments and writing systems papers. The course consists of lectures, student presentation of classic papers, and a final project. Cross-list: COMP 513.

ELEC 514 - WIRELESS INTEGRATED CIRCUITS AND SYSTEMS
Short Title: WIRELESS IC
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics covered include system architectures for modern wireless transceivers and transistor-level design considerations for circuit building blocks (low noise amplifier, mixer, power amplifier, etc.) in a wireless transceiver. Graduate/Undergraduate Equivalency: ELEC 414. Recommended Prerequisite(s): ELEC 305, ELEC 342, or Equivalent Courses with the Key Concepts Listed Below • Transistor-level CMOS analog circuits (basic configurations, small signal models, parasitic effects) • Frequency response of transistor-level CMOS circuits (pole/zero calculations) • Frequency response of simple passive networks (1st order and 2nd order RLC networks) • Noise analysis of transistor-level CMOS circuits (noise sources in CMOS transistors, input referred voltage/current noise for CMOS transistor-level circuits)

ELEC 515 - MACHINE LEARNING FOR RESOURCE-CONSTRAINED PLATFORMS
Short Title: EMBEDDED MACHINE LEARNING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Machine learning is in tremendous demand in numerous applications; however, its often prohibitive complexity remains a major challenge for its extensive deployment in resource constrained platforms. This course will introduce techniques which enable the development of energy/time efficient machine learning systems, taking a path from algorithm to architecture down to the circuit level. In particular, you will first learn commonly used machine learning algorithms, and then algorithm-, architecture-, circuit-level techniques for reducing the energy/time cost of machine learning systems while maintaining their powerful performance. Finally, we will do a deep dive into state-of-the-art efficient machine learning systems, such as Google's TPU and Eyeriss.
Course URL: yl150.web.rice.edu/course2019fall_home.html (http://yl150.web.rice.edu/course2019fall_home.html)

ELEC 516 - ANALOG INTEGRATED CIRCUITS
Short Title: ANALOG INTEGRATED CIRCUITS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: There has been growing interest in analog computing in both academia and industry in the era of artificial intelligence. This course provides a comprehensive introduction to various aspects of modern analog integrated circuits. Students will learn how to 1) analyze, simulate and design a complementary metal oxide semiconductor (CMOS) analog integrated circuit, 2) analyze and simulate elementary transistor stages, current mirrors, supply- and temperature-independent bias and reference circuits, and 3) explore performance evaluation using computer-aided design tools. Graduate/Undergraduate Equivalency: ELEC 516. Mutually Exclusive: Cannot register for ELEC 442 if student has credit for ELEC 516. Graduate/Undergraduate Equivalency: ELEC 442. Mutually Exclusive: Cannot register for ELEC 516 if student has credit for ELEC 442.

ELEC 517 - MICROWAVE ENGINEERING
Short Title: MICROWAVE ENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics covered include transmission line, Smith Chart, scattering parameters, impedance matching, passive microwave circuits (power divider, coupler, 180° hybrid, filter), and antenna design fundamentals. Graduate/Undergraduate Equivalency: ELEC 411. Mutually Exclusive: Cannot register for ELEC 517 if student has credit for ELEC 411.

ELEC 518 - PRINCIPLES OF BIOMEDICAL OPTICS AND ULTRASOUND
Short Title: BIOMEDICAL OPTICS & ULTRASOUND
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces the science and engineering of biomedical applications based on optics and ultrasound. Students will explore how light travels in tissue, how ultrasound waves move through fluids and solids, and how these signals interact with the body. The course also covers computer modeling tools for light and the design of sensing devices using ultrasound. By the end, students will understand the foundations of optical and ultrasound technologies that support applications such as medical imaging, disease diagnosis, therapy guidance, and brain research. Graduate/Undergraduate Equivalency: ELEC 418. Recommended Prerequisite(s): Knowledge and understanding of differential equations (or equivalent) Mutually Exclusive: Cannot register for ELEC 518 if student has credit for ELEC 418.

ELEC 519 - DATA SCIENCE AND DYNAMICAL SYSTEMS
Short Title: DATA AND SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: In many applications one is faced with the task of simulating or controlling complex dynamical systems. Such applications include for instance, weather prediction, air quality management, VLSI chip design, molecular dynamics, active noise reduction, chemical reactors, etc. In all these cases complexity manifests itself as the number of first order differential equations which arise. Model (order) reduction (MOR) seeks to replace a large-scale system described in terms of differential or difference equations by a system of much lower dimension that has nearly the same response characteristics. The ensuing methods have been an indispensable tool for speeding up the simulations arising in various engineering applications involving large-scale dynamical systems. In this course we will develop the underlying approximation theory paying particular attention to its data-driven aspects. Additional coursework required beyond the undergraduate course requirements Graduate/Undergraduate Equivalency: ELEC 439. Mutually Exclusive: Cannot register for ELEC 519 if student has credit for ELEC 439.

ELEC 520 - DISTRIBUTED SYSTEMS
Short Title: DISTRIBUTED SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Distributed systems: workstations, local area networks, server machines. Multiprocess structuring and interprocess communication. File access and memory management. User interfaces: window systems and command interpreters. Case studies of selected distributed systems. Emphasis on performance aspects of system software design. Cross-list: COMP 520.
Course URL: www.cs.rice.edu/~alc/comp520/ (http://www.cs.rice.edu/~alc/comp520/)

ELEC 521 - ADVANCED DIGITAL INTEGRATED CIRCUITS DESIGN
Short Title: ADV DIGITAL IC DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course addresses advanced issues in custom digital IC design. Topics range from physical-level analysis and modeling of new devices, interconnect, and power supply, to circuit-level design techniques for low power and high performance, to application-oriented digital circuits/systems for security and machine learning. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 426. Recommended Prerequisite(s): ELEC 326/COMP 326 or ELEC 342 or Digital Circuit Courses.

ELEC 522 - ADVANCED VLSI DESIGN
Short Title: ADV VLSI DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Design and analysis of algorithm-specific VLSI processor architectures. Topics include the implementation of pipelined and systolic processor arrays. Techniques for mapping numerical algorithms onto custom processor arrays. Course includes design project using high-level VLSI synthesis tools.
Course URL: www.owlnet.rice.edu/~elec522 (http://www.owlnet.rice.edu/~elec522/)

ELEC 523 - INTRODUCTION TO MICROFABRICATION
Short Title: INTRO TO MICROFABRICATION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Microfabrication and nanofabrication are among the most important electrical and computer engineering technologies, and are the basis of manufacturing for nearly all modern miniaturized systems. This course provides an introduction to integrated circuit device fabrication and micromachining technology, including film deposition, lithography, etching, thermal oxidation, ion implantation, impurity diffusion, contacts and interconnections, and process integration topics. Recommended Prerequisite(s): Introductory physics (mechanics, electricity and magnetism), introductory chemistry.

ELEC 524 - MOBILE AND WIRELESS NETWORKING
Short Title: MOBILE AND WIRELESS NETWORKING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): COMP 429 or ELEC 429
Description: Study of network protocols for mobile and wireless networking, particularly at the media access control, network, and transport protocol layers. Focus is on the unique problems and challenges presented by the properties of wireless transmission and host or router mobility. Cross-list: COMP 524. Recommended Prerequisite(s): COMP 421 OR ELEC 421.

ELEC 525 - VIRTUALIZATION AND CLOUD RESOURCE MANAGEMENT
Short Title: VIRTUAL & CLOUD RESOURCE MGMT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (ELEC 425 or COMP 425)
Description: Virtualized computer architectures. Processor, memory and storage virtualization techniques. Resource allocation and scheduling of virtual machines. Cloud architectures and infrastructure. Utility computing. Cross-list: COMP 525.

ELEC 526 - HIGH PERFORMANCE COMPUTER ARCHITECTURE
Short Title: HIGH PERFORM COMPUTER ARCH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Design of high performance computer systems, including shared-memory and message-passing multiprocessors and vector systems. Hardware and software techniques to tolerate and reduce memory and communication latency. Case studies and performance simulation of high-performance systems. Cross-list: COMP 526. Recommended Prerequisite(s): ELEC 425 or COMP 425

ELEC 527 - VLSI SYSTEMS DESIGN
Short Title: VLSI SYSTEMS DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A study of VLSI technology and design. MOS devices, Characteristics and fabrication. Logic design and implementation. VLSI design methodology, circuit simulation and verification. Additional course work required beyond the undergraduate course requirement. Graduate/Undergraduate Equivalency: ELEC 422. Mutually Exclusive: Cannot register for ELEC 527 if student has credit for ELEC 422.

ELEC 528 - SECURITY TOPICS OF EMBEDDED SYSTEMS
Short Title: EMBEDDED HW SYSTEMS SECURITY
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course covers wide range of topics pertaining to security of Hardware Embedded systems, including cryptographic processors, secure memory access, hardware IT protection by monitoring and watermarking FPGA security, physical and side-charmed attacks, Trojan horses. Cross-list: COMP 538. Repeatable for Credit.
Course URL: www.ece.rice.edu/~fk1/ (http://www.ece.rice.edu/~fk1/)

ELEC 529 - ADVANCED COMPUTER NETWORKS
Short Title: ADVANCED COMPUTER NETWORKS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): COMP 429 or ELEC 429
Description: This course explores advanced solutions in computer networks that are driven by the need to go beyond the best-effort capabilities of the Internet. Topics include network fault tolerance, traffic engineering, scalable data center network architectures, network support for big data processing, network support for cloud computing, extensible network control via software defined networking, denial-of-service-attack defense mechanisms. Readings from original research papers. Also include design project and oral presentation components. This course assumes students already have a good understanding of the best-effort Internet. Cross-list: COMP 529. Repeatable for Credit.
Course URL: www.clear.rice.edu/comp529/ (http://www.clear.rice.edu/comp529/)

ELEC 530 - BIOMEDICAL OPTICAL IMAGING AND APPLICATIONS
Short Title: BIOMEDICAL OPTICAL IMAG & APPL
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course first covers established optical imaging technologies and their biomedical applications. Topics include sensing optical properties and spectroscopy, ballistic imaging methods (confocal, two-photon, super-resolution, etc.), optical coherence tomography, diffuse optical tomography, photoacoustic tomography, and optical time reversal (wavefront shaping/engineering). Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 438. Recommended Prerequisite(s): Knowledge of differential equations or (equivalent). Graduate/Undergraduate Equivalency: ELEC 438. Mutually Exclusive: Cannot register for ELEC 530 if student has credit for ELEC 438.

ELEC 531 - STATISTICAL SIGNAL PROCESSING
Short Title: STATISTICAL SIGNAL PROCESSING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Graduate level course in statistical signal processing. Focuses on detection and estimation theory, and the relationships between them. Concentration on discrete-time results. Performance bounds derived from signal processing and information theoretic perspectives. Introduction to data science for classification. Recommended Prerequisite(s): Knowledge of digital signal processing and random processes.

ELEC 532 - NEURAL INTERFACE ENGINEERING LABORATORY
Short Title: NEURAL INTERFACE ENG LAB
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is designed to provide students with hands-on experience with the techniques and tools of neural engineering towards health, rehabilitation, and assistive technology applications. During the course, students will develop a deeper understanding of the underlying principles and phenomena of engineered systems interacting with the nervous system. The course will also expose students to hardware, software, and techniques that may be useful in their future coursework and careers. Students will work individually and in teams through a series of experiments. Students will also learn and use key concepts in designing experiments and testing neural interface systems, which they will use to propose and conduct a final project of their own design. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 435. Recommended Prerequisite(s): ELEC 587. Knowledge of Python or other coding equivalent. Mutually Exclusive: Cannot register for ELEC 532 if student has credit for ELEC 435.

ELEC 533 - INTRODUCTION TO RANDOM PROCESSES AND APPLICATIONS
Short Title: INTRO RANDOM PROCESSES & APPL
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Review of basic probability; Sequences of random variables; Random vectors and estimation; Basic concepts of random processes; Random processes in linear systems, expansions of random processes; Wiener filtering; Spectral representation of random processes, and white-noise integrals. Cross-list: CMOR 553, STAT 583.

ELEC 534 - HARDWARE VERIFICATION
Short Title: HARDWARE VERIFICATION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course offers an in-depth study of hardware verification methodologies, with a strong emphasis on SystemVerilog and the Universal Verification Methodology (UVM). Students will explore industry-standard verification techniques, such as constrained-random testing, functional coverage, assertion-based verification, and testbench automation. The course is designed to equip students with the essential skills for verifying complex System-on-Chip (SoC) and FPGA designs, preparing the students for careers in verification engineering. Students will spend a significant portion of the time writing and refining testbenches. Assignments and projects will provide hands-on experience with SystemVerilog and UVM-based verification environments, enabling students to gain practical experience in developing reusable, scalable, and efficient verification frameworks. Recommended Prerequisite(s): Strong foundation in digital design and proficiency in hardware description languages (HDLs) such as Verilog or VHDL and ELEC 521 or ELEC 526 or ELEC 527

ELEC 535 - INFORMATION THEORY
Short Title: INFORMATION THEORY
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to information theory concepts; basic theorems of channel coding and source coding with a fidelity criterion. The course material requires background of a first course in probability, like Rice ELEC 303.

ELEC 537 - INTELLIGENT MOBILE SYSTEMS
Short Title: INTELLIGENT MOBILE SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course focuses on building intelligent mobile systems that sense, communicate, and make decisions under tight resource constraints like limited energy, compute, and bandwidth. Students will explore wireless communication, embedded sensing, and machine learning techniques for mobile applications. Topics include wireless localization, sensor fusion, on-device AI, energy harvesting, wireless imaging, and emerging techniques like 3D mapping and neural radiance fields. The course combines both the foundational principles and the state-of-the-art research in mobile computing and embedded intelligence. Recommended Prerequisite(s): Recommended background in signal processing, wireless communication, embedded systems, networking, and machine learning.

ELEC 538 - ADVANCED WIRELESS NETWORKING
Short Title: ADVANCED WIRELESS NETWORKING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Advanced topics in next generation mobile and wireless networks. Recommended Prerequisite(s): An introductory course in networking or communications is recommended.

ELEC 539 - INTRODUCTION TO COMMUNICATION NETWORKS
Short Title: INTRO TO COMMUNICATION NETWORK
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to design and analysis of communication networks. Topics include wireless networks, media access, routing traffic modeling, congestion control, and scheduling. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 437. Mutually Exclusive: Cannot register for ELEC 539 if student has credit for ELEC 437.

ELEC 540 - FUNDAMENTALS OF BIOSENSORS IN MEDICINE
Short Title: FUND OF BIOSENSORS IN MEDICINE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The Fundamentals of Biosensors in Medicine course is designed to provide students with the tools to understand the basic parts of a biosensor, including the biorecognition layer, transducer and signal output. During the course, students will be able to design a biosensor according to the proposed application. Specific applications for implantable and wearable biosensors will be discussed.

ELEC 541 - 3D VISION: FROM AUTONOMOUS CARS TO THE METAVERSE
Short Title: ADVS IN 3D SENSING & VIS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The goals of the course are to study basic concepts, and algorithms in 3D computer vision and their integration into various applications including autonomous navigation and augmented reality systems. Topics include: cameras, camera models, stereo, structured light, LIDAR, time-of-flight, case studies on autonomous driving, augmented reality and 3D avatars. The course will involve programming and implementing basic computer vision algorithms in Matlab/Python. Students will learn the fundamentals behind various 3D sensors and 3D computer vision algorithms and how the different performance capabilities make them relevant for integration into various application domains including autonomous navigation, augmented reality and 3D avatars. Graduate/Undergraduate Equivalency: ELEC 448. Recommended Prerequisite(s): Prior knowledge of undergraduate-level linear algebra is a plus, but the course is self-contained. Mutually Exclusive: Cannot register for ELEC 541 if student has credit for ELEC 448.

ELEC 542 - GENERATIVE AI FOR IMAGE DATA
Short Title: GENERATIVE AI FOR IMAGE DATA
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will cover state-of-the-art research in modern learning-based image synthesis algorithms. Each lecture will focus on one or two important research papers published at top computer vision, machine learning, or graphics venues on a topic. Each student will be responsible for presenting and leading discussion on one lecture topic in the semester. Homework assignments and a final project will require students to code algorithms covered in class. Because deep learning algorithms typically require graphical processing units (GPUs) to run efficiently, students will use Google Colab (a free cloud environment for running python code) to complete assignments.

ELEC 543 - ADVANCED HIGH-SPEED SYSTEM DESIGN
Short Title: ADV H-S SYSTEM DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers practical aspects of high-speed system design, highlights system design and simulation challenges, and demonstrates common pitfalls and how to prevent them. In this course, students will learn how to design, do gigahertz speed PCB layout, simulate (spice and Hyperlynx), and apply good design practices to minimize both component and system noise and to ensure system design success. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 434. Recommended Prerequisite(s): Knowledge of mixed analog/digital circuits, active filters and transmission line theories. Mutually Exclusive: Cannot register for ELEC 543 if student has credit for ELEC 434.

ELEC 545 - INTRODUCTION TO DIGITAL IMAGE AND VIDEO PROCESSING
Short Title: DIGITAL IMAGE & VIDEO PROC.
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers theory and tools for representing and processing digital images and video. Topics include: multi-dimensional sampling, transforms, and filtering; human visual perception; visual scanning and display; tomographic reconstruction; image and video coding theory and standards; video streaming; and, image restoration. Recommended Prerequisite(s): Knowledge of the fundamentals of signals and systems and digital signal processing.

ELEC 546 - INTRODUCTION TO COMPUTER VISION
Short Title: INTRO TO COMPUTER VISION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An introduction to the basic concepts, algorithms and applications in computer vision. Topics include: cameras, camera models and imaging pipeline, low-level vision/image processing methods such as filtering and edge detection; mid-level vision topics such as segmentation and clustering; shape reconstruction from stereo, introduction to high-level vision tasks such as object recognition and face recognition. The course will involve programming and implementing basic computer vision algorithms in Matlab. Additional coursework required beyond the undergraduate course requirements. Additional coursework required beyond the undergraduate requirements. Cross-list: COMP 546. Graduate/Undergraduate Equivalency: ELEC 447. Mutually Exclusive: Cannot register for ELEC 546 if student has credit for ELEC 447.

ELEC 547 - INTRODUCTION TO HUMAN-MACHINE INTERFACES
Short Title: INTRO TO HUMAN-MACH INTERFACES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will expose students to relevant concepts and engineering tools for building closed-loop human-machine interfaces that are inclusive and equitable for users with diverse physical characteristics, with a focus on users with movement disabilities. The course covers signal acquisition, signal processing, information extraction, and feedback and control loop definitions. Students will also learn the basic physiology of how the human body generates movement, and how movement disorders affect the measured biosignals. They will also learn the basic principles of inclusive design and how users can be incorporated into the engineering pipeline from conception.

ELEC 548 - MACHINE LEARNING AND SIGNAL PROCESSING FOR NEURO ENGINEERING
Short Title: NEURAL SIGNAL PROCESSING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers advanced statistical signal processing and machine learning approaches for modern neuroscience data (primarily many-channel spike trains). Topics include latent variable models, point processes, Bayesian inference, dimensionality reduction, dynamical systems, and spectral analysis. Neuroscience applications include modeling neural firing rates, spike sorting, decoding. Cross-list: BIOE 548. Graduate/Undergraduate Equivalency: ELEC 483. Mutually Exclusive: Cannot register for ELEC 548 if student has credit for ELEC 483.

ELEC 549 - COMPUTATIONAL PHOTOGRAPHY
Short Title: COMPUTATIONAL PHOTOGRAPHY
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Computational photography is an emerging field that aims to overcome the limitations of conventional digital imaging and display devices by using novel optics, signal processing and computer vision to perform more efficient and accurate measurement as well as produce more compelling and meaningful visualizations of the world around us. It is a convergence of many areas, such as optics, computer vision, computer graphics, image processing, photography, and so on. We will cover topics such as computational sensors with assorted pixel, mobile camera control, light field capture and rendering, computational flash photography, computational illumination for appearance acquisition and 3D reconstruction, reflectance transformation imaging, light transport analysis and novel displays.

ELEC 550 - ALGORITHMIC ROBOTICS
Short Title: ALGORITHMIC ROBOTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): COMP 321 and COMP 215
Description: Robots have fascinated people for generations. Today, robots are built for applications as diverse as exploring remote planets, de-mining war zones, cleaning toxic waste, assembling cars, inspecting pipes in industrial plants and mowing lawns. Robots are also interacting with humans in a variety of ways: robots are museum guides, robots assist surgeon sin life threatening operations, and robotic cars can drive us around. The field of robotics studies not only the design of new mechanisms but also the development of artificial intelligence frameworks to make these mechanism useful in the physical world, integrating computer science, engineering, mathematics and more recently biology and sociology, in a unique way. This class will present fundamental algorithmic advances that enable today's robots to move in real environments and plan their actions. It will also explore fundamentals of the field of Artificial Intelligence through the prism of robotics. The class involves a significant programming project. Cross-list: COMP 550, MECH 550. Graduate/Undergraduate Equivalency: ELEC 450. Mutually Exclusive: Cannot register for ELEC 550 if student has credit for ELEC 450.

ELEC 551 - MODERN COMMUNICATION THEORY AND PRACTICE
Short Title: MODERN COMM. THEORY & PRACTICE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This is an upper-level course in digital communications, which is designed to prepare students for engineering work in high-tech industries and for graduate work in communications, signal processing, and computer systems. The course covers basic concepts and useful tools for design and performance analysis of transmitters and receivers in the physical layer of a communication system, including multiple antenna MIMO systems. A hands-on laboratory using a state-of-the-art radio testbed illustrates course concepts. Additional coursework required beyond the undergraduate course requirements. Mutually Exclusive: Cannot register for ELEC 551 if student has credit for ELEC 430. Graduate/Undergraduate Equivalency: ELEC 430. Mutually Exclusive: Cannot register for ELEC 551 if student has credit for ELEC 430.

ELEC 552 - OPERATING SYSTEMS AND CONCURRENT PROGRAMMING
Short Title: OP SYS/CONCURRENT PROGRAMMING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (COMP 215 and COMP 321)
Description: Introduction to the design, construction, and analysis of concurrent programs with an emphasis on operating systems, including filing systems, schedulers, and memory allocators. Specific attention is devoted to process synchronization and communication within concurrent programs. Additional coursework required beyond the undergraduate course requirements. Cross-list: COMP 521. Graduate/Undergraduate Equivalency: ELEC 421. Mutually Exclusive: Cannot register for ELEC 552 if student has credit for ELEC 421.

ELEC 553 - MOBILE AND EMBEDDED SYSTEM DESIGN AND APPLICATION
Short Title: MOBILE & EMBEDDED SYSTEM
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: ELEC 553 introduces mobile and embedded system design and applications to students and provides them hands-on design experience. It consists of three interlearning parts: lectures, student project, and student presentations. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 424. Mutually Exclusive: Cannot register for ELEC 553 if student has credit for ELEC 424.

ELEC 554 - COMPUTER SYSTEMS ARCHITECTURE
Short Title: COMPUTER SYSTEMS ARCHITECTURE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Evolution of key architecture concepts found in advanced uniprocessor systems. Fundamental and advanced pipelining techniques and associated issues for improving processor performance. Illustrated with RISC processors such as the ARM processor. Examine several metrics for processor performance, such as Amdahl's law. Key concepts of data and program memory systems found in modern systems with memory hierarchies and cashes. Perform experiments in cache performance analysis. Influence of technology trends, such as Moore's law, on processor implementation Approaches for exploiting instruction level parallelism, such as VLIW. Introduction to parallel and multicore architectures. Introduction to processor architectures targeted for imbedded applications.Additional coursework required beyond the undergraduate course requirements. Cross-list: COMP 554. Graduate/Undergraduate Equivalency: ELEC 425. Mutually Exclusive: Cannot register for ELEC 554 if student has credit for ELEC 425.

ELEC 555 - IMAGING AND VISION FOR ROBOTICS
Short Title: IMAGING & VISION FOR ROBOTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course explores the fundamental properties of light propagation, optical instruments, imaging systems, algorithms for image processing, 3D image reconstruction, and their applications in autonomous navigation and remote sensing. It emphasizes a system approach to the analysis and design of optical systems from an engineering perspective, focusing on the physical and technical constraints to select appropriate lenses, cameras, and algorithms to design and integrate optical systems into autonomous platforms. Additionally, the course will involve programming and implementation of basic computer vision algorithms in MATLAB and/or Python. Students will also gain insights into various 3D sensors and reconstruction algorithms, understanding how their different performance capabilities make them suitable for various application domains. Recommended Prerequisite(s): Prior knowledge of undergraduate-level optics is a plus, but the course is self-contained.

ELEC 556 - INTRODUCTION TO COMPUTER NETWORKS
Short Title: INTRO TO COMPUTER NETWORKS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Network architectures, algorithms, and protocols. Local- and Wide-area networking. Intra- and inter-domain routing. Transmission reliability. Flow and congestion control. TCP/IP. Multicast. Quality of Service. Network Security - Networked applications. Additional coursework required beyond the undergraduate course requirements. Cross-list: COMP 556. Graduate/Undergraduate Equivalency: ELEC 429. Recommended Prerequisite(s): COMP 321 Mutually Exclusive: Cannot register for ELEC 556 if student has credit for ELEC 429.

ELEC 557 - ARTIFICIAL INTELLIGENCE
Short Title: ARTIFICIAL INTELLIGENCE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): COMP 310 and (STAT 310 or ECON 307 or STAT 312 or STAT 331 or ELEC 303) and (MATH 354 or MATH 355 or CAAM 335 or CMOR 302)
Description: This is a foundational course in artificial intelligence, the discipline of designing intelligent agents. The course will cover the design and analysis of agents that do the right thing in the face of limited information and computational resources. The course revolves around two main questions: how agents decide what to do, and how they learn from experience. Tools from computer science, probability theory, and game theory will be used. Interesting examples of intelligent agents will be covered, including poker playing programs, bots for various games (e.g. WoW), DS1 -- the spacecraft that performed an autonomous flyby of Comet Borrely in 2001, Stanley -- the Stanford robot car that won the Darpa Grand Challenge, Google Maps and how it calculates driving directions, face and handwriting recognizers, Fedex package delivery planners, airline fare prediction sites, and fraud detectors in financial transactions. Additional coursework required beyond the undergraduate course requirements. Cross-list: COMP 557. Graduate/Undergraduate Equivalency: ELEC 440. Mutually Exclusive: Cannot register for ELEC 557 if student has credit for ELEC 440.
Course URL: www.owlnet.rice.edu/~comp440 (http://www.owlnet.rice.edu/~comp440/)

ELEC 558 - DIGITAL SIGNAL PROCESSING
Short Title: DIGITAL SIGNAL PROCESSING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Methods for analysis of discrete-time signals and design of discrete-time systems including topics of: discrete-time linear systems, difference equations, z-transforms, discrete convolution, stability, discrete-time Fourier transforms, analog-to-digital and digital-to-analog conversion, digital filter design, discrete Fourier transforms, fast Fourier transforms, multi-rate signal processing, filter banks, and spectral analysis. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 431. Mutually Exclusive: Cannot register for ELEC 558 if student has credit for ELEC 431.

ELEC 559 - IMAGE AND VIDEO COMPRESSION ALGORITHMS AND STANDARDS
Short Title: IMAGE AND VIDEO COMPRESSION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to the basic theory of image and video coding and comprehensive coverage of modern techniques used in current video coding standards and in advanced standards currently in development. Course projects include hands-on experience with actual reference software used in video coding standard development activities. Coverage includes protocols used for video streaming. Graduate/Undergraduate Equivalency: ELEC 459. Recommended Prerequisite(s): Undergraduate background in Electrical Engineering signal & systems Mutually Exclusive: Cannot register for ELEC 559 if student has credit for ELEC 459.

ELEC 560 - PHYSICS OF SENSOR MATERIALS AND NANOSENSOR TECHNOLOGY
Short Title: PHYSICS OF SENSORS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics covered include MEMS, MOEMS, and NEMS systems along with special materials such as liquid crystals, piezoelectrics, memory metal, and topological insulators. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 460. Mutually Exclusive: Cannot register for ELEC 560 if student has credit for ELEC 460.

ELEC 561 - QUANTUM VACUUM ENGINEERING
Short Title: QUANTUM VACUUM ENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A survey and discussion on seminal works on engineered vacuum-mediated modifications to material properties; introduction to the quantum vacuum, light-matter interactions, and QED research. Recommended Prerequisite(s): Undergraduate quantum physics (ELEC 361 or PHYS 311 or equivalent) and basic linear algebra.

ELEC 562 - OPTOELECTRONIC DEVICES
Short Title: OPTOELECTRONIC DEVICES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course provides an introduction to the fundamental principles of semiconductor optoelectronic devices. After reviewing the basic elements of quantum mechanics of electrons and photons, light-matter interaction (including laser oscillations), and semiconductor physics (band structure, heterostructures and alloys, optical processes), we will study the details of modern semiconductor devices for the generation, detection, and modulation of light. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 462. Mutually Exclusive: Cannot register for ELEC 562 if student has credit for ELEC 462.

ELEC 563 - INTRODUCTION TO SOLID STATE PHYSICS I
Short Title: INTRO TO SOLID STATE PHYSICS I
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Fundamental concepts of crystalline solids, including crystal structure, band theory of electrons, and lattice vibration theory. Cross-list: PHYS 563.

ELEC 564 - SOLID-STATE PHYSICS II
Short Title: INTRO SOLID STATE PHYSICS II
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Continuation of PHYS 563, including scattering of waves by crystals, transport theory, and magnetic phenomena. Cross-list: PHYS 564.

ELEC 565 - SOLID STATE MATERIALS AND DEVICE APPLICATIONS
Short Title: SOLID STATE MATERIAL & APPS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces fundamental concepts in solid state physics, including crystal structure and symmetry, phonons, electrons and holes, energy band structure, light-matter interactions. The lectures will discuss the applications of these fundamentals in heat transfer, electron scattering and optical properties in solids, as well as in optoelectronic devices. The course also introduces emerging materials, such as low-dimensional materials, perovskites, topological materials. Recommended Prerequisite(s): Knowledge of quantum mechanics and solid state physics

ELEC 566 - NANOPHOTONICS AND METAMATERIALS
Short Title: NANOPHOTONICS & METAMATERIALS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course will discuss basic concepts of nanophotonics and focus on what metamaterials are, how they work and how to build them. The course will conclude with applications of various meta-devices and upcoming research topics.

ELEC 568 - INTRODUCTION TO QUANTUM COMPUTING WITH QISKIT
Short Title: QUANTUM COMPUTING WITH QISKIT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Quantum information science and technology have been rapidly developed amid the global quantum research effort on quantum computing, communication, simulation and sensing. Significant progress has been made in quantum computing, demonstrating unprecedented quantum advantage over classical computers on specific computation tasks. This course will cover the engineering and mathematics aspects of quantum computing and algorithms, as well as discuss software implementation using Qiskit on Python platform and hardware implementation using real IBM quantum computers. Graduate/Undergraduate Equivalency: ELEC 468. Recommended Prerequisite(s): Linear Algebra Mutually Exclusive: Cannot register for ELEC 568 if student has credit for ELEC 468.

ELEC 569 - ULTRAFAST OPTICAL PHENOMENA
Short Title: ULTRAFAST OPTICAL PHENOMENA
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers the generation, propagation, and measurement of short laser pulses, of duration less than one picosecond. Concepts include mode locking, the effects of dispersion, optical pulse amplification, and time-domain non-linear optical phenomena. Intended as an introduction to ultrafast phenomena for graduate students or advanced undergraduates; a basic understanding of electromagnetic waves and of quantum mechanics is assumed. Cross-list: PHYS 569.

ELEC 570 - DISTRIBUTED METHODS FOR OPTIMIZATION AND MACHINE LEARNING
Short Title: DISTRIBUTED OPT AND ML
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will provide a comprehensive presentation of modern design and analysis methods for distributed and decentralized algorithms for signal processing, optimization, control and machine learning applications. The course will focus on mathematical analysis techniques for the iteration, computational and communication complexity of distributed data processing methods over networks, where data is generated, stored or processed by groups of computational units or agents connected via communication channels over networks. The aim is to introduce modern approaches for distributed information processing with a deep understanding on the effects of communication constraints, network topology, computational resources, and robustness. The contents of this course lie in the intersection of network science, optimization and machine learning. Topics will cover the classical literature in distributed decision making, opinion dynamics, distributed optimization, decentralized control, to more recent topics in distributed machine learning, federated learning, and social learning. Recommended Prerequisite(s): Linear Algebra, Probability Theory, Nonlinear Optimization, Numerical Analysis
Course URL: cauribe.rice.edu/ece677/ (http://cauribe.rice.edu/ece677/)

ELEC 571 - IMAGING AT THE NANOSCALE
Short Title: IMAGING AT THE NANOSCALE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A survey of the techniques used in imaging micron and nanometer structures with an emphasis on applications in chemistry, physics, biology, and engineering. The course includes an introduction to scanning probe, submicron optical, and electron microscopies, as well as discussions on the fundamental and practical aspects of image acquisition, artifacts, filtering, and machine learning analysis of such data. Homeworks will involve some familiarity and proficiency with Matlab. The final project will include analysis of the student's own research data.

ELEC 572 - FINITE ELEMENT METHOD FOR MULTIPHYSICS MODELING
Short Title: MULTIPHYSICS MODELING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will provide a hands-on experience on the modeling of micro and nano systems based on the mutual interaction among different physical phenomena. COMSOL Multiphysics, based on the Finite Element Method (FEM), will be utilized as flexible modeling tool to learn how to design a wide range of devices or describe coupled physical mechanisms including electromagnetic waves, heat transfer, fluid dynamics and mass transport. The course will focus in particular on the interaction between light and nanomaterials and how electromagnetic heat dissipation can play a major role in different applications Recommended Prerequisite(s): Basic electromagnetism and basic calculus

ELEC 573 - NETWORK SCIENCE AND ANALYTICS
Short Title: NETWORK SCIENCE AND ANALYTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course provides an introduction to complex networks, their structure, and function, with examples from engineering, biology, and social sciences. Topics include spectral graph theory, notions of centrality, community detection, random graph models, inference in networks, opinion dynamics, and contagion phenomena. Our main goal is to study network structures and how they can be leveraged to better understand data defined on them. Recommended Prerequisite(s): Linear algebra, probability and statistics, and basic ability to program in Python.

ELEC 574 - UBIQUITOUS AND WEARABLE COMPUTING
Short Title: UBQ AND WEARABLE COMPUTING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Wireless and mobile computing, affordable sensors and interaction devices being woven into our daily life and invisible, has created boundless opportunities for in-the-world computing applications that can transform our lives. This course will introduce students to the field of Ubiquitous and Wearable Computing -- a multidisciplinary research area that draws from sensors, machine learning, signal processing, as well as human computer interaction. This class combines lectures, hands-on exercises and assignments, reading state of the art research papers, class discussions and a final project.

ELEC 575 - LEARNING FROM SENSOR DATA
Short Title: LEARNING FROM SENSOR DATA
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Basic information theoretic metrics and probabilistic machine learning tools for signals, images, and other data acquired from sensors, including graphical models, density estimation, principal components analysis, support vector machines, and source separation. Additional course work required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 475. Mutually Exclusive: Cannot register for ELEC 575 if student has credit for ELEC 475. Graduate/Undergraduate Equivalency: ELEC 475. Recommended Prerequisite(s): Introductory background in probability theory and statistics. Mutually Exclusive: Cannot register for ELEC 575 if student has credit for ELEC 475.

ELEC 576 - A PRACTICAL INTRODUCTION TO DEEP MACHINE LEARNING
Short Title: INTRODUCTION TO DEEP LEARNING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Deep Machine Learning has recently made many advances in difficult perceptual tasks, including object and phoneme recognition, and natural language processing. However, the field has a steep learning curve, both conceptually and practically. The point of this course is to engage students by jumping into the deep end, and building their own architectures and algorithms. Cross-list: COMP 576. Mutually Exclusive: Cannot register for ELEC 576 if student has credit for COMP 647.

ELEC 578 - INTRODUCTION TO MACHINE LEARNING
Short Title: INTRO TO MACHINE LEARNING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is a graduate level introduction to concepts, methods, best practices, and theoretical foundations of machine learning. Topics covered include regression, classification, regularization, kernels, clustering, dimension reduction, decision trees, ensemble learning, and neural networks. Additional work is required for graduate students beyond the undergraduate requirement. Graduate/Undergraduate Equivalency: ELEC 478. Recommended Prerequisite(s): Basic statistics and probability, linear algebra, and programming in R or Python are required. Mutually Exclusive: Cannot register for ELEC 578 if student has credit for ELEC 478.

ELEC 580 - QUANTUM MECHANICS AND REAL-WORLD APPLICATIONS
Short Title: QUANTUM MECH AND APPLICATIONS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will provide a basic understanding of the principles of applied quantum mechanics, with examples of real-world applications. A foundation is laid for advanced topics in the areas of lasers, microwave and optical detectors, nanoelectronics, quantum computers, quantum sensors, etc. Senior undergraduate students and junior graduate students in the areas of quantum engineering, nanotechnology, photonics and electronics, especially experimentalists, will find this course useful. Graduate/Undergraduate Equivalency: ELEC 461. Recommended Prerequisite(s): Basic knowledge of: (1) calculus, linear algebra, complex number, vector operation, differential equations; (2) classical mechanics; (3) classical electromagnetics; (4) atomic structure, chemical boding; (5) basic quantum mechanics, including static Schrodinger equation. Mutually Exclusive: Cannot register for ELEC 580 if student has credit for ELEC 461.

ELEC 581 - INTRODUCTION TO QUANTUM INFORMATION SCIENCE AND ENGINEERING
Short Title: QUANTUM INFORMATION PROCESSING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Quantum information science and engineering (QISE) have been rapidly developed amid the global quantum research effort on quantum computing, communication, simulation and sensing. Development and innovation in these quantum applications necessitate understanding of the core concepts of the quantum information science and knowledge of leading physical platforms for implementation.This course will serve the purpose to introduce the physics and engineering aspects of quantum information processing systems. The course will be divided into four parts, starting with an introduction of concepts and basic ingredients for quantum information processing. The second part will focus on qubit operations, utilizing simplified two-level systems for discussions of atom-field interaction and coherent state manipulations. Part three will cover leading physical platforms for quantum information processing, including trapped ions, neutral atoms, solid-state spins, and superconducting qubits. In the last part, extended topics about applications of quantum information will be discussed if time permits, such as quantum communications, quantum repeaters, and quantum error correction. Recommended Prerequisite(s): Quantum mechanics

ELEC 582 - IMAGING OPTICS
Short Title: IMAGING OPTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course covers the fundamental properties of light propagation and interaction with matter under the approximations of geometrical optics and scalar wave optics, as well as the fundamentals of optical microscopy. The course emphasizes a system approach to the analysis and design of optical systems from a user and an engineering perspective, focusing on the physical intuition and underlying mathematical tools, and application of the physical concepts to topical engineering domains such as a selection of microscopy techniques. Students will have direct hands-on experience with optics and optical imaging systems in the classroom. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 487. Mutually Exclusive: Cannot register for ELEC 582 if student has credit for ELEC 487.

ELEC 583 - ELECTROMAGNETISM AND THE BRAIN
Short Title: ELECTROMAGNETISM AND THE BRAIN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Human brain activity is a specific form bioelectromagnetism commonly referred to as “brain signals” generated by EM fields that can be detected with electric and magnetic sensors. This class will develop your intuition of brain signals through lectures and in-class physics and biophysics modeling. Topics include EM, biophysics, spectral analysis, forward modeling, reciprocity, source localization, and the electrode/insulator design. Your final team project will build a finite element model (FEM) of brain activity and/or biophysical model and analyze those signals in a specific application. Graduate/Undergraduate Equivalency: ELEC 481. Recommended Prerequisite(s): Introductory courses in physics and time-series signal analysis, e.g., ELEC 242 Mutually Exclusive: Cannot register for ELEC 583 if student has credit for ELEC 481.

ELEC 584 - QUANTUM PHYSICS IN SEMICONDUCTOR DEVICES
Short Title: QUANTUM SEMICONDUCTOR DEVICES
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The objective of this graduate level course is an understanding of the quantum physics and the operation of advanced semiconductor devices. The first part of the course is focused on understanding of advanced quantum concepts related to semiconductor materials and devices, such as energy bands in solids, energy states in quantum wells, density of states for 3D, 2D, and 1D, tunneling, electronic transport, and heterostructures. The second part of the course is focused on the understand-ing and application of the quantum structures for semiconductor devices, including junction field effect transistors (JFETs), heterojunction bipolar transistors (HBTs), high electron mobility transistors (HEMTs), LEDs and lasers, and power devices. Recommended Prerequisite(s): Basic knowledge of: (1) semiconductor physics, including crystal structure, energy bands, density of states, dopants, equilibrium statistics, non-equilibrium behavior and electronic transport; (2) operation of semiconductor pn junctions and pn diodes. basic knowledge of: (1) semiconductor physics, including crystal structure, energy bands, density of states, dopants, equilibrium statistics, non-equilibrium behavior and electronic transport; (2) operation of semiconductor pn junctions and pn diodes. Mutually Exclusive: Cannot register for ELEC 584 if student has credit for ELEC 484.

ELEC 587 - INTRODUCTION TO NEUROENGINEERING: MEASURING AND MANIPULATING NEURAL ACTIVITY
Short Title: INTRO TO NEUROENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will serve as an introduction to quantitative modeling of neural activity and the methods used to stimulate and record brain activity. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 380. Mutually Exclusive: Cannot register for ELEC 587 if student has credit for ELEC 380.

ELEC 588 - THEORETICAL NEUROSCIENCE I: BIOPHYSICAL MODELING OF CELLS AND CIRCUITS
Short Title: THEORETICAL NEUROSCIENCE
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course presents the theoretical foundations of cellular and systems neuroscience from a quantitative perspective, integrating mathematical modeling, computational tools, and data analysis. Students will develop and apply differential equations, probabilistic models, and reverse correlation techniques to analyze neural activity and synaptic interactions. The course combines traditional lectures with student-led presentations in a seminar-style format. Coursework includes problem sets, coding-based assignments, and group projects. MATLAB or Python proficiency is strongly recommended. Cross-list: CMOR 615, NEUR 615. Graduate/Undergraduate Equivalency: ELEC 488. Mutually Exclusive: Cannot register for ELEC 588 if student has credit for ELEC 488.

ELEC 589 - NEURAL COMPUTATION
Short Title: NEURAL COMPUTATION
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: How does the brain work? Understanding the brain requires sophisticated theories to make sense of the collective actions of billions of neurons and trillions of synapses. Word theories are not enough; we need mathematical theories. The goal of this course is to provide an introduction to the mathematical theories of learning and computation by neural systems. These theories use concepts from dynamical systems (attractors, oscillations, chaos) and concepts from statistics (information, uncertainty, inference) to relate the dynamics and functions of neural networks. We will apply these theories to sensory computation, learning and memory, and motor control. Students will learn to formalize and mathematically answer questions about neural computations, including “what does a network compute?”, “how does it compute?”, and “why does it compute that way?” Prerequisites: knowledge of calculus, linear algebra, and probability and statistics. Graduate/Undergraduate Equivalency: ELEC 489. Mutually Exclusive: Cannot register for ELEC 589 if student has credit for ELEC 489.

ELEC 590 - GRADUATE NON-THESIS RESEARCH PROJECTS
Short Title: GR NON-THESIS RES PROJECTS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Theoretical and experimental investigations under staff direction. Instructor Permission Required. Repeatable for Credit.

ELEC 591 - GRADUATE ELECTRICAL ENGINEERING RESEARCH PROJECTS-VERTICALLY INTEGRATED PROJECTS
Short Title: GRAD ELEC ENG'G RESEARCH VIP
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Vertically Integrated Projects (VIP) teams include students from multiple years working on one larger, multi-year project defined by the instructor. Instructor Permission Required. Graduate/Undergraduate Equivalency: ELEC 491. Repeatable for Credit.

ELEC 592 - GRADUATE PRE-THESIS RESEARCH PROJECT EXPLORATION
Short Title: PRE-THESIS PROJECT EXPLORATION
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hour: 1
Restrictions: Enrollment is limited to students with a major in Electrical & Computer Eng.. Enrollment is limited to Graduate level students. Enrollment limited to students in a Doctor of Philosophy degree.
Course Level: Graduate
Description: Theoretical and experimental investigations under faculty direction.

ELEC 594 - MECE CAPSTONE PROJECT
Short Title: MECE CAPSTONE PROJECT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students. Enrollment limited to students in a Master of Electrical Comp Eng degree.
Course Level: Graduate
Description: Capstone projects for students in the professional master’s in electrical and computer engineering (MECE) program. In order to obtain the MECE degree, students must complete two semesters of this course. This course serves as graded academic credit for capstone projects, which have the goal of producing a completed product, algorithm, design, or similar entity. Capstone projects aim to have students develop practical and technical skills in the area that they are interested in for employment after the MECE program. Projects will be overseen by the instructor usually along with academic and/or industrial collaborators. Typically, students will take this course during both the second and third semesters of the MECE program after having completed a foundations course in the first semester. Repeatable for Credit.

ELEC 595 - PRACTICUM IN ELECTRICAL AND COMPUTER ENGINEERING
Short Title: PRACTICUM IN MECE
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Internship/Practicum
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is restricted to students in the master's of electrical and computer engineering (MECE) program. This course introduces current theoretical and applied problems encountered in ECE practice through practical internships. Students will be required to complete a paid or unpaid off-campus internship. MECE students will be required to submit a written, 10-15 page report/document summarizing the ECE experience developed during the internship, as well documenting how the internship was instrumental to the MECE course of study. Instructor Permission Required. Repeatable for Credit.

ELEC 598 - INTRODUCTION TO ROBOTICS
Short Title: INTRODUCTION TO ROBOTICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to the kinematics, dynamics, and control of robot manipulators and to applications of artificial intelligence and computer vision in robotics. Additional work requied for Graduate course. Cross-list: COMP 598, MECH 598. Graduate/Undergraduate Equivalency: ELEC 498. Mutually Exclusive: Cannot register for ELEC 598 if student has credit for ELEC 498.

ELEC 599 - FIRST YEAR GRAD STUDENT PROJECTS
Short Title: 1ST YEAR GRAD STUDENTS PROJECT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 6
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Supervised project required of all first-year graduate students in the Ph.D. program.

ELEC 602 - NEURAL MACHINE LEARNING AND DATA MINING II
Short Title: NEURAL MACHINE LEARNING II
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ELEC 502 or COMP 502 or STAT 502
Description: Advanced topics in ANN theories, with a focus on learning high-dimensional complex manifolds with neural maps (Self-Organizing Maps, Learning Vector Quantizers and variants). Application to data mining, clustering, classification, dimension reduction, sparse representation. The course will be a mix of lectures and seminar discussions with active student participation, based on most recent research publications. Students will have access to professional software environment to implement theories. Cross-list: COMP 602, STAT 602. Repeatable for Credit.
Course URL: www.ece.rice.edu/~erzsebet/NMLcourseII.html (http://www.ece.rice.edu/~erzsebet/NMLcourseII.html)

ELEC 603 - FOUNDATIONAL AND CURRENT TOPICS IN NANOPHOTONICS RESEARCH
Short Title: CURRENT NANOPHOTONICS RESEARCH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This is a course for graduate students in the area of 21st century Photonics, broadly defined (including plasmonics, nanophotonics, plasmonic photocatalysis, metasurfaces, active photonic devices). Students who should take this course would be students enrolled in Applied Physics, Physical Chemistry, Physics, Chemical Physics, Chemistry, and Photonics in Electrical Engineering. The course will begin with introductory lectures based on landmark papers that built the field and inspired its subfields. Subsequently, each student selects and presents a critical summary of several research papers related to their chosen research topic. Repeatable for Credit.

ELEC 605 - COMPUTATIONAL ELECTRODYNAMICS AND NANOPHOTONICS
Short Title: ELECTRODYNAMICS & NANOPHOTONIC
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: See PHYS 605. Cross-list: PHYS 605. Repeatable for Credit.

ELEC 631 - ADVANCED MACHINE LEARNING
Short Title: ADVANCED MACHINE LEARNING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: There is a long history of algorithmic development for solving inferential and estimation problems that play a central role in a variety of learning, sensing, and processing systems, including medical imaging scanners, numerous machine learning algorithms, and compressive sensing, to name just a few. Until recently, most algorithms for solving inferential and estimation problems have iteratively applied static models derived from physics or intuition. In this course, we will explore a new approach that is based on "learning" various elements of the problem including i) stepsizes and parameters of iterative algorithms, ii) regularizers, and iii) inverse functions. For example, we will explore a new approach for solving inverse problems that is based on transforming an iterative, physics-based algorithm into a deep network whose parameters can be learned from training data. For a range of different inverse problems, deep networks have been shown to offer faster convergence to a better quality solution. Specific topics to be discussed include: Ill-posed inverse problems, iterative optimization, deep learning, neural networks, learning regularizers. This is a "reading course," meaning that students will read and present classic and recent papers from the technical literature to the rest of the class in a lively debate format. Discussions will aim at identifying common themes and important trends in the field. Students will also get hands on experience with optimization problems and deep learning software through a group project. Repeatable for Credit.

ELEC 632 - ADVANCED TOPICS IN IMAGE AND VIDEO PROCESSING
Short Title: ADV TOPIC IMAGE&VIDEO PROCESS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar on topics of current research interest in image and video processing. Students participate in selecting and presenting papers from technical literature. Discussions aim at identifying common themes and important trends in the field.

ELEC 660 - QUANTUM INFORMATION SCIENCE AND TECHNOLOGY
Short Title: QUANTUM INFO
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This is a graduate seminar course on quantum information science and technology. There is currently a world-wide effort to develop technologies based on the principles of quantum mechanics that are expected to revolutionize computation, communication, and sensing. These rapid scientific and technological developments can be viewed as the second quantum revolution. Unlike the first quantum revolution, which occurred during the first few decades of the 20th century and totally changed the way we describe the universe, the second quantum revolution is about controlling individual quantum systems to a much greater extent than before, enabling even more powerful applications of quantum mechanics. Many of these new applications rely on genuinely quantum, nonintuitive concepts such as superposition and entanglement. These concepts are becoming more and more common and important in diverse scientific disciplines beyond physics, including materials science, electrical engineering, chemistry, mathematics, and computer science. We will review some of the latest published papers on quantum materials, devices, and systems, and their practical applications to quantum technologies. Recommended Prerequisite(s): Understanding of undergraduate-level classical and quantum mechanics, electromagnetism, statistical mechanics, and solid state physics.

ELEC 677 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Laboratory, Lecture, Lecture/Laboratory, Seminar, Independent Study
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

ELEC 680 - NANO-NEUROTECHNOLOGY
Short Title: NANO-NEUROTECHNOLOGY
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will review current nanofabricated technologies for measuring, manipulating, and controlling neural activity. The course will be based on reviewing current academic literature and topics will include nano-electronic, -photonic, -mechanical, and -fluidic neural devices. Cross-list: BIOE 680.

ELEC 682 - SPOTLIGHT ON LATEST NEUROTECHNOLOGY
Short Title: SPOTLIGHT ON LATEST NEUROTECH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is a seminar format review of the latest (within the last five years) neurotechnology framed around the concept of the nervous system as a network. It has three modules: Module I discusses methods and approaches for building and mapping a neural network. Module II focuses on technologies for reading networks; and module III on tools for interacting with networks. Recommended Prerequisite(s): Basic understanding of some neurotechnology such as imaging, organoid culture, electrophysiology, genetic manipulation is beneficial, but not required. Students without any background in neuroscience or neuroengineering may have to do additional reading.

ELEC 692 - ADVANCED TOPICS IN DISTRIBUTED SYSTEMS
Short Title: ADV TOPICS IN DISTRIBUTED SYST
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: We will learn about and discuss recent advances in various areas in computer systems, including topics on security, distributed systems, networking, operating systems, and databases. The seminar will be divided into several sections, with each section focusing on one research trend. In each class, students will read one classic paper on the topic, and present two recent papers that describe the stat of the art. Students can also team up and do a semester-long research project on any relevant topics. All students will need to make a final presentation at the end of the class on a potential project idea; for students that choose to do a semester-long project, they will also submit a six-page report on their project, in addition to giving a final presentation. Instructor Permission Required. Cross-list: COMP 645. Repeatable for Credit.

ELEC 693 - ADVANCED TOPICS-COMPUTER SYSTEMS
Short Title: ADV TOPICS - COMPUTER SYSTEMS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is a discussion based seminar about state of the art embedded and digital signal processing systems, with emphasis on both hardware architectures as well as software tools, programming models, and compilers. The seminar focuses on state of the art academic and commercial offerings in these areas. Cross-list: COMP 693. Repeatable for Credit.

ELEC 698 - ECE PROFESSIONAL MASTERS SEMINAR SERIES
Short Title: ECE PROFESSIONAL MASTER SEM
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 0
Restrictions: Enrollment is limited to Graduate level students. Enrollment limited to students in a Master of Electrical Comp Eng or Master of Electrical Eng degrees.
Course Level: Graduate
Description: The Professional Masters Seminar Series presents a combination of seminars on emerging research topics in the many areas of ECE and industry-focused professional development. This course includes attendance and reports based on the seminars, colloquia, and distinguished lectures held each semester. Repeatable for Credit.

ELEC 699 - FRONTIERS OF ELECTRICAL AND COMPUTER ENGINEERING
Short Title: FRONTIERS OF ECE
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to students with a major in Electrical & Computer Eng.. Enrollment is limited to Graduate level students. Enrollment limited to students in a Doctor of Philosophy or Master of Science degrees.
Course Level: Graduate
Description: Frontiers of Electrical and Computer Engineering presents emerging research topics in the many areas of ECE. This course includes attendance and reports based on the seminars, colloquia, and distinguished lectures held each semester. Repeatable for Credit.

ELEC 800 - RESEARCH AND THESIS
Short Title: RESEARCH AND THESIS
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Repeatable for Credit.

Description and Code Legend

Note: *Internally, the university uses the following descriptions, codes, and abbreviations for this academic program. The following is a quick reference:*

Course Catalog/Schedule

- Course offerings/subject code: Courses from various subjects may apply towards this program

Home School Description and Code

- Engineering and Computing: EN

Department (or Program) Description and Code

- Electrical and Computer Engineering: ELEC

Undergraduate Minor Description and Code

- Minor in Digital Health: DIGH

Graduate Degree Description and Code

- Master of Digital Health degree: MDH

Graduate Degree Program Description and Code

- Degree Program in Digital Health: DGHT

CIP Code and Description [1]

- **DGHT** Major/Program: CIP Code/Title: *14.4701 - Electrical and Computer Engineering*
- **DIGH** Minor: CIP Code/Title: *14.4701 - Electrical and Computer Engineering*

[1] Classification of Instructional Programs (CIP) 2020 Codes and Descriptions from the National Center for Education Statistics: https://nces.ed.gov/ipeds/cipcode/.