ELECTRICAL AND COMPUTER ENGINEERING

Contact Information

Electrical and Computer Engineering
https://www.ece.rice.edu/
2057 Duncan Hall
713-348-5081

Ashutosh Sabharwal
Chair
ashu@rice.edu

The Electrical and Computer Engineering (ECE) department provides high-quality degree programs that emphasize fundamental principles, respond to the changing demands and opportunities of new technology, challenge the exceptional abilities of Rice students, and prepare students for roles of leadership in their chosen careers.

The department's seven current research areas can be grouped into four undergraduate educational specializations including: Computer Engineering; Data Science/Systems; Neuroengineering; and Photonics, Electronics, and Nano-devices.

- **Computer Engineering** topics include: computer architecture, high performance application specific systems, mobile and embedded systems, integrated circuits and antennas for medical imaging and bio-sensing, and parallel I/O for large-scale network storage systems.
- **Data Science/Systems** topics include: data acquisition, data analytics, data storage, and computing infrastructure, wireless systems, computer vision, dynamical systems and computation, networks, signal and image processing, wireless networking, pattern recognition, and scalable personal digital health.
- **Neuroengineering** topics include: neural signal processing, brain-computer interfaces at the device, circuit, and systems levels, and computational neuroscience.
- **Photonics, Electronics, and Nano-devices** topics include: quantum engineering, nanophotonics/nanospectroscopy, molecular electronics, biophotonics, ultrafast optics and optoelectronics, materials for energy, semiconductor optics and devices, multispectral imaging and terahertz imaging, and condensed matter physics/materials science.

The Electrical and Computer Engineering department offers two undergraduate degree programs. The Bachelor of Science in Electrical and Computer Engineering (BSECE) degree program is comprehensive and covers fundamental and emerging hardware and software topics. Courses, research, and design projects grouped in four areas of educational specialization prepare students for technical leadership in engineering, computing, and science careers. The ECE department also offers a Bachelor of Arts (BA) degree with a major in Electrical and Computer Engineering.

The Electrical and Computer Engineering department offers two graduate degree programs. The Master of Electrical and Computer Engineering (MECE) degree is a course-based program designed to increase a student's mastery of advanced subjects; no thesis is required. For the MECE degree, the research areas are currently presented as six educational specializations with the addition of computer vision and quantum engineering to provide additional focus on emerging topics. The MECE prepares a student to succeed and advance rapidly in today's competitive technical marketplace.

The Doctor of Philosophy (PhD) degree program prepares students for a research career in academia or industry. The PhD degree program consists of formal courses and original research conducted under the guidance of a faculty advisor, leading to a thesis. Students in the PhD program either complete a Master of Science (MS) degree as part of their program or have already completed a MS degree at another institution before enrolling in the PhD program. While students are not routinely admitted specifically to the Electrical and Computer Engineering MS degree program, the department does occasionally admit students to pursue the terminal MS degree.

Bachelor's Programs

- Bachelor of Arts (BA) Degree with a Major in Electrical and Computer Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/electrical-computer-engineering-ba/)
- Bachelor of Science in Electrical and Computer Engineering (BSECE) Degree (https://ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/electrical-computer-engineering-bsece/)

Master's Programs

- Master of Electrical and Computer Engineering (MECE) Degree (https://ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/electrical-computer-engineering-mece/)
- Master of Science (MS) Degree in the field of Electrical and Computer Engineering*

Doctoral Program

- Doctor of Philosophy (PhD) Degree in the field of Electrical and Computer Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/electrical-computer-engineering-phd/)

* *Although students are not normally admitted to a Master of Science (MS) degree program, graduate students may earn the MS as they work towards the PhD.*

Chair

Ashutosh Sabharwal

Professors

Behnaam Aazhang
Athanasios C. Antoulas
Richard G. Baraniuk
Joseph R. Cavallaro
Naomi J. Halas
Edward W. Knightly
Junichiro Kono
Michael T. Orchard
Peter J. Varman
Ashok Veeraraghavan

Associate Professors

Genevera I. Allen
Kevin Kelly
Caleb Kemere
Gururaj Naik
Jacob Robinson
John Seymour
Chong Xie
Yuji Zhao

Assistant Professors

Alessandro Alabastri
Guha Balakrishnan
Songtao Chen
Taiyun Chi
Shengxi Huang
Yingyan Lin
Lan Luan
Ankit Patel
Akane Sano
Santiago Segarra
Kevin Slagle
César Uribe
Kaiyuan Yang

Professors Emeriti

Don Herrick Johnson
Frank K. Tittel
James Young

Assistant Teaching Professors

Arko Barman
Su Chen
Joseph Young

Assistant Research Professors

Pratiksha Dongare
Rahman Doost-Mohammady

Professors in the Practice

Gene Frantz
Saad Saleh
Ray Simar, Jr.
Thanh Tran
Gary L. Woods

Lecturers

Fabrizio A. Gabbiani
Joseph Mait
Osama R. Mawlawi
Harel Shouval
Clayton Shepard

Adjunct Faculty

Ravindra Athale
Aydin Babakhani
Alexios Balatsoukas-Stimming
Gavin Britz
Michael Brogioli
Anand Dabak
Clifford C. Dacso
Christopher H. Dick
Valentin Dragoi
Henry O. Everitt
Amir H. Faraji
Wayne Goodman
Omer Gurewitz
Reinhard Heckel
Markku Juntti
Joo-won Kim
Vaishnav Krishnan
Matthew McGinley
Tarik Muharemovic
Bijan Najafi
Theodora Dorina Papageorgiou
Xaq Pitkow
Arvind Rao
David Ress
Stephan M. Schwanauer
Steve Sheafor
Sameer Sheth
Francois St-Pierre
Christoph Studer
James Suliburk
Nitin Tandon
Andreas S. Tolias
Hadley Wickham
Lin Zhong

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 & Comp. Engineering (ELEC)

ELEC 101 - ELEMENTS OF ELECTRICAL ENGINEERING
Short Title: ELEMENTS OF ELECT ENGINEERING
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment limited to students with a class of Freshman or Sophomore. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Introduction to fundamentals of electrical engineering through the hands-on design of a micro-controlled model electric car. Topics from fields of circuits, signals, computing, and sensing are covered as needed to support the student in designing systems to power, monitor, and control the vehicle's speed, and to guide its trajectory, in order to pass a series of vehicle tests. Instructor Permission Required.

ELEC 220 - FUNDAMENTALS OF COMPUTER ENGINEERING
Short Title: FUND COMPUTER ENGINEERING
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 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
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.

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) and ELEC 305 (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)
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
Prerequisite(s): ELEC 301 (may be taken concurrently)
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.ELEC 301 may be taken concurrenlty with ELEC 303.

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 and (MATH 212 or MATH 222)
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 211 or 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. Recommended Prerequisite(s): COMP 221.

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
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 332 - ELECTRONIC SYSTEMS PRINCIPLES AND PRACTICE
Short Title: ELEC SYS PRINCIPLES & PRACTICE
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 242
Description: This course covers the theory and techniques necessary to realize modern, high performance electronic systems. Design considerations for systems utilizing high speed, high frequency analog and digital integrated circuits will be covered. Students develop a microcontroller system for controlling the functions of a model electric car. Power and sensor circuits will be designed to monitor and control the vehicle's speed, and to guide its trajectory, in order to pass a series of vehicle tests. Instructor Permission Required.

ELEC 342 - ANALOG ELECTRONIC CIRCUITS
Short Title: ANALOG ELECTRONIC CIRCUITS
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 242 or ELEC 243
Description: The course starts with a review of 1st order and 2nd order linear circuits. It emphasizes time-domain techniques and discusses step and impulse responses, reviews basic device physics of a CMOS transistor, followed by a derivation of current-voltage equations.
The course also covers an in-depth analysis of large-signal behavior, linearization, and small signal models. Furthermore, it discusses single-stage and multi-stage amplifiers as well as differential amplifiers, common mode rejection ratio (CMRR), and techniques for increasing gain and improving linearity.

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.
Course URL: www.ece.rice.edu/~kono/ELEC361.html (http://www.ece.rice.edu/~kono/ELEC361.html)

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 365 - NANOMATERIALS FOR ENERGY
Short Title: NANOMATERIALS FOR ENERGY
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
Description: This course will introduce students to the fundamental science of nanomaterials. Many of the concepts will be explained by drawing from applications in sustainability (photovoltaics, solar-to-fuel conversion thermionic, thermoelectric, fuel cells). Students will design a lab demo from scratch using amongst others the infrastructure provided by the photonics measurement lab. Cross-list: MSNE 365.

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)
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 BIOE 480/BIOE 590/ELEC 480/ELEC 580/ELEC 587.

ELEC 382 - INTRODUCTION TO COMPUTATIONAL NEUROSCIENCE
Short Title: INTRO COMPUTATIONAL NEURSCI
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 methods and theories used to describe and understand neural information processing in the brain. Models covered will range from single neuron to networks for sensory, motor and learning tasks. Programming exercises will be done using Matlab. Cross-list: NEUR 382. Recommended Prerequisite(s): CAAM 210. Mutually Exclusive: Cannot register for ELEC 382 if student has credit for NEUR 582.

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 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 - EMBEDDED COMPUTER SYSTEMS PROGRAMMING
Short Title: EMBEDDED SYSTEMS PROGRAMMING
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
Description: Embedded computer systems programming focuses on the integrated design of hardware and software for system on chip devices. The course will develop an integrated foundation including principles, practices, and experimentation. Computer languages including C and C++ will be used to analyze and implement algorithms. Object-oriented programming for trees and graphs and other data structures will be explored. Embedded operating systems including Linux, peripheral interfacing, and development environments will be utilized in the laboratory. Mutually Exclusive: Cannot register for ELEC 418 if student has credit for ELEC 518. Graduate/Undergraduate Equivalency: ELEC 518. Recommended Prerequisite(s): COMP 140. ELEC 220, and (ELEC 327 or ELEC 332 or DSCI 400 or DSCI 435) Mutually Exclusive: Cannot register for ELEC 418 if student has credit for ELEC 518.

ELEC 419 - INNOVATION LAB FOR MOBILE HEALTH
Short Title: INNOVATION LAB - MOBILE HEALTH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Students with a class of Freshman may not enroll. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course will be an innovation lab for mobile health products. The students will organize themselves in groups with complementary skills and work on a single project for the whole semester. The aim will be to develop a product prototype which can then be demonstrated to both medical practitioners and potential investors. For successful projects with an operational prototype, the next steps could be applying for OWLspark (Rice accelerator program) or crowd sourcing (like Kickstarter) and/or work in Scalable Health Labs over summer. ELEC Juniors can also continue the project outcomes as a starting point for their senior design. Cross-list: BIOE 419. Graduate/Undergraduate Equivalency: ELEC 559. Mutually Exclusive: Cannot register for ELEC 419 if student has credit for ELEC 559. Repeatable for Credit.
Course URL: www.ece.rice.edu/~ashu/ELEC419.html (http://www.ece.rice.edu/~ashu/ELEC419.html)

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 221 or 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
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 427 - ADVANCED DIGITAL HARDWARE DESIGN, IMPLEMENTATION, AND OPTIMIZATION
Short Title: ADV DIGITAL DESIGN & IMPLEMENT
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 326 or COMP 326
Description: This senior level course will investigate design and implementation of modern digital signal processing, machine learning, and security algorithms in hardware (including FPGAs and ASICs). Along with learning the principals of design, students will acquire hands-on experience in hardware implementation and the use of the hardware in modern applications including but not limited to mobile phones, biomedical devices, and smart cards. Emphasis is on digital processors, design implementation on FPGA/ASIC fabrics and testing real systems on board, architectures, control, functional units, and circuit topologies for increased performance and reduced circuit size and power dissipation. Graduate/Undergraduate Equivalency: ELEC 555. Mutually Exclusive: Cannot register for ELEC 427 if student has credit for ELEC 555. Repeatable for Credit.

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 221 or 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 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 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 432 - MOBILE BIO-BEHAVIORAL SENSING
Short Title: MOBILE BIO-BEHAVIORAL SENSING
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 301
Description: In the next-generation of devices, designed for diverse fields as healthcare and education, the devices will understand the human user. At the core of this understanding will be data that is gathered from a new class of sensors, that can measure both biological and behavioral markers. This course introduces the fundamentals of bio- and behavioral sensing. Graduate/Undergraduate Equivalency: ELEC 534. Mutually Exclusive: Cannot register for ELEC 432 if student has credit for ELEC 302/ELEC 534.

ELEC 433 - ARCHITECTURE FOR WIRELESS COMMUNICATIONS
Short Title: ARCH - WIRELESS COMMUNICATIONS
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 301 and (ELEC 326 or COMP 326)
Description: This is an FPGA laboratory course. Students will embark upon a detailed study and implementation of digital communications systems. Major functional blocks of end-to-end wireless communication systems will be discussed, built, and tested in hardware. Course will also cover analysis and design of communication systems, especially modulation, demodulation and detection. Students will benefit from a combined theory-lab approach to communications and work in groups on weekly lab assignments and a major semester project. Graduate/Undergraduate Equivalency: ELEC 536. Mutually Exclusive: Cannot register for ELEC 433 if student has credit for ELEC 536.

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 - INTRODUCTION TO ENERGY-EFFICIENT MECHATRONICS
Short Title: INTRO TO MECHATRONICS
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 242 or ELEC 243
Description: Introduction to electromechanical systems, focusing on motor mechanics, electric drives & electronics, & modern digital control algorithms. Covers basic principles of electromechanical energy conversion & motor control. Students are introduced to energy efficiency considerations of modern electric drives. Includes hands-on laboratory projects involving digital computer control of various motor types. Cross-list: MECH 435. Graduate/Undergraduate Equivalency: ELEC 532. 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 and MECH 343) or (MATH 355 and MECH 343) or (CAAM 335 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 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 and (ELEC 303 or STAT 310 or ECON 307 or STAT 312 or STAT 315 or DSCI 301) and (CAAM 334 or CAAM 335 or MATH 354 or MATH 355) and (COMP 382 or COMP 582) and COMP 310
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 441 - COMPUTATIONAL IMAGING
Short Title: COMPUTATIONAL IMAGING
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: A upper-level introduction to imaging systems as an integral part of the sense-process-decide-act cycle. This cycle is central to the operation of any goal-directed system, biological or engineered. Students will gain a basic understanding of the mechanisms by which information about a scene is encoded on an electro-magnetic wave. Furthermore, the students will learn to analyze the information extraction process realized via the imaging chain of front-end optics, transduction, and post-processing. The objective of the course is to understand the limits of modern image formation and how optics, photonic-to-electronic transduction, and post-detection processing can be jointly designed to enable imagers with unique capabilities.

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 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 446 - MOBILE DEVICE APPLICATIONS PROJECT
Short Title: MOBILE DEVICE APPLICATIONS
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
Description: Connected mobile devices require updated programming models and design concepts to take advantage of their capabilities. We will explore applications primarily on the Apple iPhone and iPad but will also cover smart watches, Google Android and intelligent voice assistants like Amazon Echo and Google Home. We will briefly touch on the development of web services to support mobile applications. The course culminates with a large project taking up most of the second half of the semester. Although the curriculum centers around and teaches iOS and Xcode, final projects may be completed in any major mobile system including Android and Alexa, etc. Cross-list: COMP 446. Recommended Prerequisite(s): COMP 310 or prior Object Oriented Programming experience highly recommended.

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 301 or ELEC 475 or COMP 314 or ELEC 322 or COMP 330
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. 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 450 - 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 Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (COMP 221 or 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 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 - SOLID STATE PHYSICS
Short Title: SOLID STATE PHYSICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment limited to students with a class of Junior or Senior. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 261
Description: This is a course for juniors and seniors whose specialization is in photonics, electronics, and nanoengineering. This course will provide an introduction to elementary topics in solid state physics, including free electron Fermi gas, crystal structure, reciprocal lattice, lattice vibrations, electronic band structure, Bloch electron dynamics, superconductivity, magnetism, and optical properties.

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 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
Description: The first half of this course develops the basic machine learning tools for signals images, and other data acquired from sensors. Tools covered include principal components analysis, regression, support vector machines, neural networks, and deep learning. The second half of this course overviews a number of applications of sensor data science in neuroscience, image and video processing, and machine vision. 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 COMP 140 or DSCI 101) and (CAAM 334 or CAAM 335 or MATH 355 or MATH 354) or (ELEC 301 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. Recommended Prerequisite(s): (STAT 405 OR CAAM 210 OR COMP 140 OR DSCI 101) AND (CAAM 334 OR CAAM 335 OR MATH 355 OR MATH 354) OR (ELEC 301 OR DSCI 301 OR STAT 310 OR STAT 311) Mutually Exclusive: Cannot register for ELEC 478 if student has credit for DSCI 303.

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): (MATH 354 or MATH 355 or CAAM 335) and (ELEC 303 or STAT 305 or STAT 310 or ECON 307) and (CAAM 210 or COMP 140)
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. Graduate/Undergraduate Equivalency: ELEC 548. Recommended Prerequisite(s): ELEC 475 and STAT 413 and COMP 540 and (ELEC 242 or ELEC 243) Mutually Exclusive: Cannot register for ELEC 483 if student has credit for ELEC 548.

ELEC 485 - FUNDAMENTALS OF MEDICAL IMAGING I
Short Title: FUND MEDICAL IMAGING 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 Upper-Level
Description: This course will introduce basic principles of image acquisition, formation and processing of several medical imaging modalities such as X-Ray, CT, MRI, and US that are used to evaluate the human anatomy. The course also includes visits to a clinical site to gain experience with the various imaging modalities covered in class. Cross-list: BIOE 485, COMP 485. Graduate/Undergraduate Equivalency: ELEC 585. Recommended Prerequisite(s): MATH 211 and MATH 212. Mutually Exclusive: Cannot register for ELEC 485 if student has credit for ELEC 585.

ELEC 486 - FUNDAMENTALS OF MEDICAL IMAGING II
Short Title: FUND MEDICAL IMAGING II
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 485 or BIOE 485 or COMP 485
Description: This course focuses on functional imaging modalities used specifically in nuclear medicine such as Gamma cameras, SPECT, and PET imaging. The course will introduce the basic principles of image acquisition, formation, processing and the clinical applications of these imaging modalities and lays the foundations for understanding the principles of radiotracer kinetic modeling. A trip to a clinical site in also planned to gain experience with nuclear medicine imaging. Cross-list: BIOE 486, COMP 486. Graduate/Undergraduate Equivalency: ELEC 586. Mutually Exclusive: Cannot register for ELEC 486 if student has credit for ELEC 586.

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.

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
Description: We present the theoretical foundations of cellular and systems neuroscience from distinctly quantitative point of view. We develop the mathematical and computational tools as they are needed to model, analyze, visualize and interpret a broad range of experimental data. Cross-list: CAAM 415, NEUR 415. Graduate/Undergraduate Equivalency: ELEC 588. Recommended Prerequisite(s): CAAM 210 or MATH 211 or CAAM 335 or MATH 355. 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: CAAM 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
Short Title: SENIOR DESIGN
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
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 for both 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 497 - DESIGN OF ANALOG PRINTED CIRCUIT BOARDS
Short Title: ANALOG PRINTED CIRCUIT BOARDS
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Lecture/Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ELEC 494 (may be taken concurrently) or BIOE 451 (may be taken concurrently) or MECH 407 (may be taken concurrently)
Description: This course covers the basics of designing, fabricating, and testing daughter cards for microcontrollers such as the Arduino. Using PCB design software such as Eagle, students will design, fabricate, and test their printed circuit board. Prerequisites may be taken concurrently.

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
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 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 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
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: CAAM 508, MECH 508.

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
Prerequisite(s): STAT 310 or ECON 307 or STAT 331 or ELEC 331 or ELEC 303 or STAT 312
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.

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 - EMBEDDED COMPUTER SYSTEMS PROGRAMMING
Short Title: EMBEDDED SYSTEMS PROGRAMMING
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: Embedded computer systems programming focuses on the integrated design of hardware and software for system on chip devices. The course will develop an integrated foundation including principles, practices, and experimentation. Computer languages including C and C++ will be used to analyze and implement algorithms. Object-oriented programming for trees and graphs and other data structures will be explored. Embedded operating systems including Linux, peripheral interfacing, and development environments will be utilized in the laboratory. Additional course work required beyond the undergraduate course requirement. Mutually Exclusive: Cannot register for ELEC 518 if student has credit for ELEC 418. Graduate/Undergraduate Equivalency: ELEC 418. Recommended Prerequisite(s): COMP 140. ELEC 220, and (ELEC 327 or ELEC 332 or DSCI 400 or DSCI 435) 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. 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 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 - INTRODUCTION TO ENERGY-EFFICIENT MECHATRONICS
Short Title: INTRO TO MECHATRONICS
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 electromechanical systems, focusing on motor mechanics, electric drives & electronics, & modern digital control algorithms. Covers basic principles of electromechanical energy conversion & motor control. Students are introduced to energy efficiency considerations of modern electric drives. Includes hands-on laboratory projects involving digital computer control of various motor types. Additional coursework required beyond the undergraduate course requirements. Cross-list: MECH 535. Graduate/Undergraduate Equivalency: ELEC 435. 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: CAAM 583, STAT 583.

ELEC 534 - MOBILE BIO-BEHAVIORAL SENSING
Short Title: MOBILE BIO-BEHAVIORAL SENSING
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 the next-generation of devices, designed for diverse fields as healthcare and education, the devices will understand the human user. At the core of this understanding will be data that is gathered from a new class of sensors, that can measure both biological and behavioral markers. This course introduces the fundamentals of bio- and behavioral sensing. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 432. Mutually Exclusive: Cannot register for ELEC 534 if student has credit for ELEC 432.

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 536 - ARCHITECTURE FOR WIRELESS COMMUNICATIONS
Short Title: ARCH - WIRELESS COMMUNICATIONS
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 FPGA laboratory course. Students will embark upon a detailed study and implementation of digital communications systems. Major functional blocks of end-to-end wireless communication systems will be discussed, built, and tested in hardware. Course will also cover analysis and design of communication systems, especially modulation, demodulation and detection. Students will benefit from a combined theory-lab approach to communications and work in groups on weekly lab assignments and a major semester project. Graduate/Undergraduate Equivalency: ELEC 433. Mutually Exclusive: Cannot register for ELEC 536 if student has credit for ELEC 433.

ELEC 537 - COMMUNICATION NETWORKS
Short Title: COMMUNICATION NETWORKS
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 introduction to design and analysis of communication networks. Topics include wireless networks, medium access, routing, traffic modeling, congestion control, and scheduling. Cross-list: MECH 537.

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 542 - NEURAL METHODS FOR IMAGE SYNTHESIS
Short Title: NEURAL METHODS FOR IMAGE SYNTH
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 544 - ADVANCED DSP
Short Title: ADVANCED DSP
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 cover advanced topics in FIR and IIR digital filter design, advanced topics in signal processing algorithms, especially in FFTs and high speed convolution and correlation, and in wavelet based signal processing and the discrete wavelet transform. The course will be one-half lecture based and one-half project based.

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 - COMPUTER VISION
Short Title: COMPUTER VISION
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 goal of computer vision is to make sense of the three dimensional world from captured images and videos. This requires understanding how light interacts with objects in the environment and then captured by a camera. The goal is to solve problems such as estimating 3D shape of an environment (How does Kinect work?), how to detect and recognize people (How to build your own iPhoto?), detect and track how things move. The course provides an introduction to solving such problems using vision tools such as feature detection, image segmentation, motion estimation, image mosaics, 3D shape reconstruction, and object recognition.

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 221 or 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 221 or 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.
Course URL: www.clear.rice.edu/comp421/ (http://www.clear.rice.edu/comp421/)

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 - ADVANCED DIGITAL HARDWARE DESIGN, IMPLEMENTATION, AND OPTIMIZATION
Short Title: ADV DIGITAL DESIGN & IMPLEMENT
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 graduate level course will investigate design and implementation of modern digital signal processing, machine learning, and security algorithms in hardware (including FPGAs and ASICs). Along with learning the principals of design, students will acquire hands-on experience in hardware implementation and the use of the hardware in modern applications including but not limited to mobile phones, biomedical devices, and smart cards. Emphasis is on digital processors, design implementation on FPGA/ASIC fabrics and testing real systems on board, architectures, control, functional units, and circuit topologies for increased performance and reduced circuit size and power dissipation. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 427. Mutually Exclusive: Cannot register for ELEC 555 if student has credit for ELEC 427. Repeatable for Credit.

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
Prerequisite(s): COMP 221 or 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. Additional coursework required beyond the undergraduate course requirements. Cross-list: COMP 556. Graduate/Undergraduate Equivalency: ELEC 429. 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 ECON 382 or STAT 312 or STAT 331 or ELEC 331 or ELEC 303) and (MATH 354 or MATH 355 or CAAM 335)
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 - INNOVATION LAB FOR MOBILE HEALTH
Short Title: INNOVATION LAB - MOBILE HEALTH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will be an innovation lab for mobile health products. The students will organize themselves in groups with complementary skills and work on a single project for the whole semester. The aim will be to develop a product prototype which can then be demonstrated to both medical practitioners and potential investors. For successful projects with an operational prototype, the next steps could be applying for OWLspark (Rice accelerator program) or crowd sourcing (like Kickstarter) and/or work in Scalable Health Labs over summer. ELEC Juniors can also continue the project outcomes as a starting point for their senior design. Additional course work required beyond the undergraduate course requirements. Cross-list: BIOE 534. Graduate/Undergraduate Equivalency: ELEC 419. Mutually Exclusive: Cannot register for ELEC 559 if student has credit for ELEC 419. Repeatable for Credit.
Course URL: www.ece.rice.edu/~ashu/ELEC419.html (http://www.ece.rice.edu/~ashu/ELEC419.html)

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 - OPTICAL TECHNIQUES FOR IMAGING THROUGH SCATTERING MEDIA
Short Title: IMAGING THROUGH SCATTERS
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 basics of Physical optics, and Fourier optics with a strong emphasis on its applications to imaging through scattering media.

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 - MATERIALS FOR ENERGY AND PHOTOCATALYSIS
Short Title: MATERIALS FOR ENERGY&CATALYSIS
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 the basic physics and chemistry of solar energy conversion and storage devices, and the current state of the art and future challenges in materials for energy and photocatalaysis. In addition, physical and chemical characterization techniques will be covered.

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 567 - NANO-OPTICS
Short Title: NANO-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 goal of this course is to understand concepts of light localization and light-matter interactions on the nanoscale, and to familiarize the students with the state-of-the-art research in the field of nano-optics.

ELEC 568 - LASER SPECTROSCOPY
Short Title: LASER SPECTROSCOPY
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 theory and practice of laser spectroscopy as applied to atomic and molecular systems. The course covers fundamentals of spectroscopy, lasers and spectroscopic light sources, high resolution and time resolved laser spectroscopy with applications in atmospheric chemistry, environmental science and medicine. Repeatable for Credit.

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: Seminar
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: The first half of this course develops the basic machine learning tools for signals images, and other data acquired from sensors. Tools covered include principal components analysis, regression, support vector machines, neural networks, and deep learning. The second half of this course overviews a number of applications of sensor data science in neuroscience, image and video processing, and machine vision. 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. Repeatable for Credit.

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 577 - ALGORITHMS AND OPTIMIZATION FOR DATA SCIENCE
Short Title: OPTIMIZATION FOR DATA SCIENCE
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 this course, we study algorithms for analyzing data with provable performance, statistical, and computational guarantees. We focus on applications in machine learning and signal processing. Topics include: efficient algorithms for convex optimization, inverse problem, low-rank and sparse models, dimensionality reduction, and randomized algorithms. Recommended Prerequisite(s): MATH 355 and (ECON 307 or STAT 310) or digital circuit courses.

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 DSCI 303.

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 482.

ELEC 584 - FUNDAMENTALS OF HUMAN NEUROIMAGING
Short Title: HUMAN NEUROIMAGING
Department: Neurosciences
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 methods and results for human brain imaging. Describes the physical and physiological mechanisms of image formation. Provides examples from clinical and basic research, particularly in visual cortex. Emphasis on magnetic resonance imaging, but surveys other imaging modalities including PET, optical, and EEG/MEG source localization. Course taught at Baylor College of Medicine. Cross-list: NEUR 584. Mutually Exclusive: Cannot register for ELEC 584 if student has credit for ELEC 484.

ELEC 585 - FUNDAMENTALS OF MEDICAL IMAGING I
Short Title: FUND MEDICAL IMAGING 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: This course will introduce basic principles of image acquisition, formation and processing of several medical imaging modalities such as X-Ray, CT, MRI, and US that are used to evaluate the human anatomy. The course also includes visits to a clinical site to gain experience with the various imaging modalities covered in class. Additional coursework required beyond the undergraduate course requirements. Cross-list: BIOE 591. Graduate/Undergraduate Equivalency: ELEC 485. Mutually Exclusive: Cannot register for ELEC 585 if student has credit for ELEC 485.

ELEC 586 - FUNDAMENTALS OF MEDICAL IMAGING II
Short Title: FUND MEDICAL IMAGING 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: This course focuses on functional imaging modalities used specifically in nuclear medicine such as Gamma cameras, SPECT, and PET imaging. The course will introduce the basic principles of image acquisition, formation, processing and the clinical applications of these imaging modalities and lays the foundations for understanding the principles of radiotracer kinetic modeling. A trip to a clinical site in also planned to gain experience with nuclear medicine imaging. Additional coursework required beyond the undergraduate course requirements. Cross-list: BIOE 596. Graduate/Undergraduate Equivalency: ELEC 486. Mutually Exclusive: Cannot register for ELEC 586 if student has credit for ELEC 486.

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 BIOE 480/BIOE 590/ELEC 380/ELEC 480/ELEC 580.

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: We present the theoretical foundations of cellular and systems neuroscience from distinctly quantitative point of view. We develop the mathematical and computational tools as they are needed to model, analyze, visualize and interpret a broad range of experimental data. Additional course work required beyond the undergraduate course requirements. Cross-list: CAAM 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 Hours: 1-3
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. Department Permission Required.

ELEC 594 - MECE CAPSTONE PROJECT
Short Title: MECE CAPSTONE PROJECT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
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. 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
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 - TOPICS IN NANOPHOTONICS
Short Title: TOPICS IN NANOPHOTONICS
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 course is designed as a cornerstone for the NSF funded Integrative Graduate Research and Educational Training (IGERT) program in nanophotonics. It is also an official "home" for the Laboratory for Nanophotonics (LANP) seminars that serve as a forum for the interaction between researchers in nanophotonics at Rice. The conversational atmosphere of the seminar continues the relatively unstructured spirit of the interaction that has been the hallmark of past LANP meetings and collaboration. The course is open to graduate students who are interested in pursuing research in Nanophotonics. Repeatable for Credit.

ELEC 604 - NANO-OPTICS
Short Title: NANO-OPTICS
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: The goal of this seminar is to understand concepts of light localization and light-matter interactions on the nanoscale, and to familiarize the students with the state-of-the art research in the field of nano-optics through student-led research paper presentations and discussions.

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 635 - NETWORK INFORMATION THEORY
Short Title: NETWORK 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
Prerequisite(s): ELEC 535
Description: This course will introduce the key building blocks in network information theory: multiple access, broadcast, relay and interference channels. Further topics will be explored as part of projects.

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 691 - NANOPHOTONICS, SPECTROSCOPY, AND MATERIALS FOR SUSTAINABILITY
Short Title: NANOPHOT, SPECT, MAT4SUST
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 seminar will cover the contributions that nanophotonic concepts and advanced spectroscopy techniques can make to the development and characterization of novel materials for energy and sustainability. We will cover nanophotonic concepts for novel materials and characterization techniques, ultrafast and nanoscale spectroscopy techniques, and applications in energy and sustainability. Repeatable for Credit.

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 694 - HOW TO BE A CHIEF TECHNOLOGY OFFICER
Short Title: HOW TO BE A CTO
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: Survey of the component and standards trends that are the basis of personal computers and digital appliances with the aim of predicting technologies, solutions, and new products five years into the future. Examples of these technologies are dual Core processors, iPods and their evolution, mobile wireless data devices, and even Google vs. Microsoft. Students will each pick a topic important to the digital lifestyle and through a series of one-on-one sessions develop a depth of understanding that is presented to the class. Formerly "Future Personal Computing Technologies." Cross-list: COMP 694. Repeatable for Credit.
Course URL: www.ece.rice.edu/Courses/694/ (http://www.ece.rice.edu/Courses/694/)

ELEC 695 - ADVANCED TOPICS IN COMMUNICATIONS AND STATISTICAL SIGNAL PROCESSING
Short Title: INNOVATIONS IN MOBILE HEALTH
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: Section 1: - Innovations in Mobile Health - In this seminar, we will study the merging area of mobile health, enabled by prevalent data connectivity, highly portable medical sensors, smart-phones and inexpensive cloud computing. The seminar will involve a mix of lectures, paper reading, case studies and group projects. The course is suitable for both undergraduate (junior and seniors) and graduate students. The course is part of the new ECE initiative on scalable health (http://sh.rice.edu). Open to both undergraduate and graduate students. Section 2: - This is a graduate seminar class focused on the role of information theory in engineering wireless networks. Students will survey, read, and present both classic as well as recent papers in the area. 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, Master of Electrical Comp Eng or Master of Electrical Eng 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: ELEC

Department Description and Code

- Electrical and Computer Engineering: ELEC

Undergraduate Degree Descriptions and Codes

- Bachelor of Arts degree: BA
- Bachelor of Science in Electrical and Computer Engineering degree: BSECE

Undergraduate Major Description and Code

- Major in Electrical and Computer Engineering (both BA and BSECE degrees): ELEC

Undergraduate Major Areas of Specialization Descriptions and Attribute Codes*

- Area of Specialization in Computer Engineering (BA, BSECE, and MECE degrees): EECE
- Area of Specialization in Computer Vision (MECE degree): EECV
- Area of Specialization in Data Science (MECE degree): EEDS
- Area of Specialization in Data Science/Systems (BA and BSECE degrees): EEDS
- Area of Specialization in Neuroengineering (BA, BSECE, and MECE degrees): EENE
- Area of Specialization in Photonics, Electronics, and Nano-devices (BA and BSECE degrees): EEPH
- Area of Specialization in Quantum Engineering (MECE degree): EEQE
- Area of Specialization in Wireless Systems (MECE degree): EESY

Please Note: *Areas of Specialization are department/program-specific and are not formally recognized academic credentials. Unlike Major Concentrations, Areas of Specialization do not appear on the student's official academic transcript, etc. Students may informally choose to follow more than one Area of Specialization (or pre-specified collections of elective courses), however, when declaring their major they should identify and declare one Area of Specialization with the Office of the Registrar.*

Graduate Degree Descriptions and Codes

- Master of Electrical and Computer Engineering degree: MECE
- Master of Science degree: MS
- Doctor of Philosophy degree: PhD

Graduate Degree Program Description and Code

- Degree Program in Electrical and Computer Engineering (MECE, MS, and PhD degrees): ELEC

CIP Code and Description [1]

- **ELEC** Major/Program: CIP Code/Title: *14.4701 - Electrical and Computer Engineering*

* *Systems Use Only: this information is used solely by internal offices at Rice University (such as OTR, GPS, etc.) and primarily within student information systems and support.*

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