Electrical and Computer Engineering

Contact Information
Electrical and Computer Engineering
https://www.ece.rice.edu/
Abercrombie Lab A204
713-348-4020
Edward W. Knightly
Professor, Sheafor-Lindsay Chair and Department Chair
knightly@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 research areas include: Computer Engineering; Data Science; Neuroengineering; Photonics, Electronics, and Nano-devices; and Systems.

- **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** topics include: data acquisition, data analytics, data storage, and computing infrastructure.
- **Neuroengineering** topics include: neural signal processing, brain-computer interfaces at the device, circuit, and systems levels.
- **Photonics, Electronics, and Nano-devices** topics include: 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.
- **Systems** topics include: communications systems, dynamical systems and computation, networks, signal and image processing, wireless networking, pattern recognition, scalable personal healthcare, and computational neuroscience and neuroengineering

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

The Electrical and Computer Engineering department offers two graduate degree programs. The Master of Electrical Engineering (MEE) degree is a course-based program designed to increase a student's mastery of advanced subjects; no thesis is required. The MEE 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 dissertation. Students in the PhD program complete a Master of Science (MS) degree as part of their program; the Electrical and Computer Engineering department does not admit students for a terminal MS degree.

**Bachelor's Programs**
- Bachelor of Arts (BA) Degree with a Major in Electrical Engineering (ga.rice.edu/programs-study/departments-programs/engineering/electrical-engineering/electrical-engineering-ba)
- Bachelor of Science in Electrical Engineering (BSEE) Degree (ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/electrical-engineering-bsee)

**Master's Programs**
- Master of Electrical Engineering (MEE) Degree (ga.rice.edu/programs-study/departments-programs/engineering/electrical-computer-engineering/electrical-engineering-mee)
- 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 (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**
Edward W. Knightly

**Professors**
Behnaam Aazhang
Athanasios C. Antoulas
Richard G. Baraniuk
Joseph R. Cavallaro
Naomi J. Halas
Junichiro Kono
Michael Orchard
Ashutosh Sabharwal
Peter J. Varman
Lin Zhong

**Associate Professors**
Kevin Kelly
Ashok Veeraraghavan

**Assistant Professors**
Palash Bharadwaj
Reinhard Heckel
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 ELECTRICAL 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 207 - MATHEMATICAL TOOLS AND METHODS IN ELECTRICAL AND COMPUTER ENGINEERING

**Short Title:** MATHEMATICAL TOOLS AND METHODS IN ELECTRICAL AND COMPUTER ENGINEERING  
**Department:** Electrical & Computer Eng.  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**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:** This course is based on matrix theory and linear algebra, with emphasis given to useful topics in Electrical and Computer Engineering. These topics include the evaluation of systems of equations (algebraic and differential), vector spaces, determinants, eigenvalues, similarity, and positive definite matrices. Numerical methods for solving ordinary and partial differential equations are also included.
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 students with a major in Computer Science, Engineering Division, Electrical & Computer Eng. or Electrical Engineering. 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

ELEC 238 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Laboratory, Lecture, Seminar, Internship/Practicum
Credit Hours: 1-4
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.
Course URL: www.owlnet.rice.edu/~elec243

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 reception of information by electronic means, elementary signal theory; time and frequency-domain analysis; sampling theorem. Digital information theory; digital transmission of analog signals; error-correcting codes.

ELEC 242 - FUNDAMENTALS OF ELECTRICAL ENGINEERING II
Short Title: FUND ELEC ENGINEERING 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 Lower-Level
Prerequisite(s): ELEC 241
Corequisite: ELEC 244
Description: Formulation and solution of equations describing electric circuits and electromechanical systems. Behavior of dynamic systems in the time and frequency domains. Basic electronic devices and circuits, including diodes, transistors, optoelectronics, gates, and amplifiers. Introduction to feedback control and digital systems. 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: 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.
Course URL: owlnet.rice.edu/~elec243

ELEC 244 - FUNDAMENTALS OF ELECTRICAL ENGINEERING II LABORATORY
Short Title: FUND ELEC ENGINEERING II 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
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 - ELECTRONIC MATERIALS AND QUANTUM DEVICES  
**Short Title:** ELECTRONIC MATERIALS  
**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:** An overview of fundamental topics in physical electronics including a semiclassical approach to the electrical, magnetic, and optical properties of materials as well as an introduction to quantum mechanics, atomic physics, crystal lattices, and electronic band structure.

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 281 - HISTORY OF NUMBERS AND GAMES OF CHANCE  
**Short Title:** NUMBER HISTORY/GAMES OF CHANCE  
**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 Lower-Level  
**Description:** Starting with the colorful history of numbers, we discover their use to characterize chance or luck through probability; students will participate in one major project and submit a report/application areas include physics, computer science, sports, finance, etc. The course is accessible to sophomores and juniors in science, engineering or business. Cross-list: COMP 281, STAT 281.

ELEC 301 - 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 241 and (MATH 354 or MATH 355 or CAAM 335)  
**Corequisite:** ELEC 303  
**Description:** An introduction to probability theory and statistics with applications to electrical engineering problems in signal processing, communications and control; probability spaces, conditional probability, independence, random variables, distribution and density functions, random vectors, signal detection and parameter estimation. Instructor Permission Required.

ELEC 302 - INTRODUCTION TO SYSTEMS  
**Short Title:** INTRODUCTION TO SYSTEMS  
**Department:** Electrical & Computer Eng.  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** ELEC 301 or MATH 355 or CAAM 335  
**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 - 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 301 (may be taken concurrently)  
**Description:** 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 concurrently with ELEC 303.
ELEC 305 - INTRODUCTION TO PHYSICAL ELECTRONICS  
Short Title: INTRO PHYSICAL ELECTRONICS  
Department: Electrical & Computer Eng.  
Grade Mode: Standard Letter  
Course Type: Lecture/Laboratory  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Prerequisite(s): ELEC 261  
Description: Survey of devices and physical principles that are used in modern electronic systems such as cellphones: diodes, transistors, integrated circuits; scaling and Moore’s Law; transmission lines; signal integrity; antennas.

ELEC 306 - APPLIED ELECTROMAGNETICS  
Short Title: APPLIED ELECTROMAGNETICS  
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 212 and PHYS 102  
Description: An introduction to the theory of static and dynamic electromagnetic fields with a focus on engineering applications. Principles will be illustrated with applications in various areas. Topics include computational electromagnetics, transmission lines, antennas, electromagnetic interference, and signal propagation in high speed circuits.

ELEC 322 - APPLIED ALGORITHMS AND DATA STRUCTURES  
Short Title: APPL ALGORITHMS&DATA STRUCTURE  
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 211 and COMP 280 (may be taken concurrently)  
Description: Design analysis of computer algorithms and data structures useful for applied problems. Laboratory assignments will use these techniques in conjunction with advanced programming methods. Cross-list: COMP 314. Recommended Prerequisite(s): COMP 280 or may be taken the same semester.

ELEC 323 - PRINCIPLES OF PARALLEL PROGRAMMING  
Short Title: FUNDAMENTALS OF PARALLEL PROGRAM  
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  
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. SECTION 001: 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

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
Prerequisite(s): ELEC 242 or PHYS 201
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, thermolectic, 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)
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: BIOL 380, NEUR 383. Mutually Exclusive: Credit cannot be earned for ELEC 380 and BIOE 480/BIOE 590/ELEC 480/ELEC 580/ELEC 587.
ELEC 381 - FUNDAMENTALS OF NERVE AND MUSCLE
ELECTROPHYSIOLOGY
Short Title: FUND OF ELECTROPHYSIOLOGY
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An introduction to cellular electrophysiology. Includes development of whole-cell models for neurons and muscle (cardiac and skeletal muscle) cells, based on ion channel currents obtained from whole-cell voltage-clamp experiments. Material balance equations are developed for various ions and chemical signaling agents (e.g., second messengers). Numerical methods are introduced for solving the ordinary and partial differential equations associated with these models. Several types of cell models are discussed ranging from neurons and muscle cells to sensory cells of mechanoreceptors, auditory hair cells and photoreceptor cells. Volume conductor boundary-value problems frequently encountered in electrophysiology are posed. Course provides a cellular basis for the interpretation of macroscopic bioelectric signals such as the electrocardiogram (ECG), electromyogram (EMG), electroretinogram (ERG) and electroencephalogram. Cross-list: BIOE 381.

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: Credit cannot be earned for ELEC 382 and NEUR 582.

ELEC 395 - TRANSFER CREDIT - JUNIOR
Short Title: TRANSFER CREDIT - JUNIOR
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
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 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 327 or COMP 427 or COMP 541 or COMP 429 or COMP 556 or ELEC 429 or ELEC 556 or COMP 421 or COMP 521 or ELEC 552 or ELEC 421 or ELEC 437 or ELEC 539
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. Mutually Exclusive: Credit cannot be earned for ELEC 410 and ELEC 510.

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: Credit cannot be earned for ELEC 419 and ELEC 559. Repeatable for Credit.

Course URL: 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: Credit cannot be earned for ELEC 421 and ELEC 552.
Course URL: 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
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: Credit cannot be earned for ELEC 422 and 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: Credit cannot be earned for ELEC 424 and ELEC 553.
Course URL: www.ruf.rice.edu/~mobile/elec424/

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 caches. 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: Credit cannot be earned for ELEC 425 and ELEC 554.
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 principles 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: Credit cannot be earned for ELEC 427 and 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  
Course URL: 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: Course in digital communications, designed to prepare students for engineering work in high-tech industries and for graduate work in communications, signal processing, and computer systems. Covers basic concepts and useful tools for design and performance analysis of transmitters and receivers in the physical layer of a communication system. Graduate/Undergraduate Equivalency: ELEC 551. Mutually Exclusive: Credit cannot be earned for ELEC 430 and 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: Credit cannot be earned for ELEC 431 and 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: Credit cannot be earned for ELEC 432 and 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  
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: Credit cannot be earned for ELEC 433 and ELEC 536.
ELEC 435 - INTRODUCTION TO ENERGY-EFFICIENT MECHATRONICS  
**Short Title:** INTRO TO MECHATRONICS  
**Department:** Electrical & Computer Eng.  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** ELEC 303 or ELEC 243 and ELEC 244 or (CAAM 335 or MATH 354 or MATH 355 or STAT 312 or STAT 331 or ELEC 331 or ELEC 303) and (MATH 354 or MATH 355 or CAAM 335)  
**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. 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 304 and 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: Credit cannot be earned for ELEC 437 and ELEC 539.

ELEC 438 - WIRELESS NETWORKING FOR UNDER-RESOURCED URBAN COMMUNITIES  
**Short Title:** WIRELESS NETWG UNDER-RESRC'D  
**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 Rice Networks Group and the non-profit organization Technology For All have recently deployed a state-of-the-art wireless network in one of Houston's most economically disadvantaged neighborhoods. The objective of this network is to empower under-resourced communities with access to technology and educational and work-at-home tools. In this course project teams will perform measurement studies both in the Rice Networks Lab and in the East End neighborhood to characterize the system capacity; optimize placement of wireless nodes; study the effects of traffic and channel characteristics on system-wide performance; and plan deployment of additional nodes to extend the coverage area.

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):** 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 Borrelly 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: Credit cannot be earned for ELEC 440 and ELEC 557.

**Course URL:** [www.owlnet.rice.edu/~comp440](http://www.owlnet.rice.edu/~comp440)
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 tasks such as object 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: Credit cannot be earned for ELEC 447 and 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: Credit cannot be earned for ELEC 450 and ELEC 550.

ELEC 450 - 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: Credit cannot be earned for ELEC 460 and 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: Credit cannot be earned for ELEC 462 and ELEC 562.
Course URL: 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 562. Mutually Exclusive: Credit cannot be earned for ELEC 475 and ELEC 575.

ELEC 477 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Lecture, Seminar, Laboratory
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) and (CAAM 335 or MATH 355)
Description: This course provides an introduction to concepts, methods, best practices, and theoretical foundations of machine learning. Topics covered include regression, classification, kernels, clustering, decision trees, ensemble learning, empirical risk minimization and regularization, and learning theory. Graduate/Undergraduate Equivalency: ELEC 578. Recommended Prerequisite(s): ELEC 301 and ELEC 475. Mutually Exclusive: Credit cannot be earned for ELEC 478 and ELEC 578.

ELEC 481 - COMPUTATIONAL NEUROSCIENCE AND NEURAL ENGINEERING
Short Title: COMP/NEUROSCIENCE/NEURAL ENGR
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An introduction to the anatomy and physiology of the brain. Includes basic electrophysiology of nerve and muscle. Develops mathematical models of neurons, synaptic transmission and natural neural networks. Leads to a discussion of neuromorphic circuits which can represent neuron and neural network behavior in silicon. Recommendation: Knowledge of electrical circuits, operational amplifier circuits and ordinary differential equations. Involves programming Matlab. Cross-list: BIOE 481, NEUR 481. Graduate/Undergraduate Equivalency: ELEC 583. Recommended Prerequisite(s): Knowledge of basic electrical and operational amplifier circuits; and ordinary differential equations. Mutually Exclusive: Credit cannot be earned for ELEC 481 and ELEC 583.

ELEC 482 - PHYSIOLOGICAL CONTROL SYSTEMS
Short Title: PHYSIOLOGICAL CONTROL SYSTEMS
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: A study of the somatic and autonomic nervous system control of biological systems. Simulation methods, as well as, techniques common to linear and nonlinear control theory are used. Also included is an introduction to sensors and instrumentation techniques. Examples are taken from the cardiovascular, respiratory, and visual systems. Cross-list: BIOE 482. Graduate/Undergraduate Equivalency: ELEC 582. Recommended Prerequisite(s): Knowledge of basic electrical and operational amplifier circuits; and ordinary differential equations. Mutually Exclusive: Credit cannot be earned for ELEC 482 and ELEC 582.
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
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 354 or MATH 355 or CAAM 335) and (ECON 303 or STAT 305 or STAT 310) 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: Credit cannot be earned for ELEC 483 and ELEC 548.

ELEC 484 - 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 Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
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 430. Graduate/Undergraduate Equivalency: ELEC 584.
Mutually Exclusive: Credit cannot be earned for ELEC 484 and ELEC 584.

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: Credit cannot be earned for ELEC 485 and 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: Credit cannot be earned for ELEC 486 and ELEC 586.

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 MATH 335 or MATH 355. Mutually Exclusive: Credit cannot be earned for ELEC 488 and 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: Credit cannot be earned for ELEC 489 and 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.
Course URL: www.ece.rice.edu/uploadedFiles/ECE/ECE_Home/Academics/ECE_forms/ELEC%20490.pdf

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. Mutually Exclusive: Credit cannot be earned for ELEC 491 and ELEC 591. Repeatable for Credit.

ELEC 492 - NAKATANI RIES FELLOWSHIP
Short Title: NAKATANI RIES FELLOWSHIP
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The Nakatani RIES: Research & International Experiences for Students connects undergraduates with the best of science & engineering research in the U.S. or Japan. While abroad, fellows participate in language, cultural, and communication training and conduct a hands-on research internship in a leading science or engineering research host laboratory. Instructor Permission Required.

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: TRANSFER CREDIT - SENIOR
Grade Mode: Transfer
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.
attention to its data-driven aspects. In this course such requirements. The ensuing methods have been an indispensable dimensionality of these complex systems to a level that is amendable to real time control. MOR has been advised as a means to reduce the expediency requirements of interactive design, optimization, or that inevitably arise in such cases are often too complex to meet the control of nonlinear systems such as backstepping, sliding mode and singular perturbations Feedback linearization control. Other methods in the linearization method, converse theorems. Selected topics in nonlinear methods. Lyapunov stability: Stability definitions, Lyapunov's direct 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 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 level students.
Prerequisite(s): MATH 354 or MATH 355 or CAAM 335
Description: This course covers the basics of designing, fabricating, and testing robotics and 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 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: 3
Restrictions: Enrollment is limited to Undergraduate level students.
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 printed circuit boards. Prerequisites may be taken concurrently.

ELEC 507 - NONLINEAR 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, 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 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 processing.
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

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
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
Prerequisite(s): COMP 327 or COMP 427 or COMP 541 or COMP 429 or COMP 556 or ELEC 429 or ELEC 556 or COMP 421 or COMP 521 or ELEC 421 or COMP 552 or ELEC 437 or COMP 539
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. Mutually Exclusive: Credit cannot be earned for ELEC 510 and 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 - SUSTAINABILITY, ENERGY, AND INFORMATION TECHNOLOGY: AN INTERDISCIPLINARY APPROACH
Short Title: SUSTAINABILITY & ENERGY TECHNOLOGY: AN INTERDISCIPLINARY APPROACH
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment limited to students with a class of Graduate.
Course Level: Graduate
Description: An interdisciplinary course addressing the energy issues facing computing in the coming decade and beyond. In a student research-driven format we will ask how IT may address its power consumption problem and serve as a vehicle for energy efficiency, sustainability, and reduced carbon emissions across all human activity. Cross-list: COMP 514.
Course URL: www.cs.rice.edu/~kvp1/spring2008/comp514.htm

ELEC 515 - ENERGY-EFFICIENT MACHINE LEARNING SYSTEMS
Short Title: ENERGY-EFFICIENT MACHINE
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 efficient machine learning systems, taking a path from algorithm to architecture down to the circuit level.
ELEC 518 - ENERGY EFFICIENCY IN MODERN SYSTEMS
Short Title: ENERGY EFFICIENCY MODERN SYS
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: Energy efficiency has become critically important for modern computing systems, from battery-powered mobile devices to wall-powered high-performance servers. The course presents the fundamentals of energy characteristics of modern systems, and introduces basic energy-saving mechanisms and methodologies for system energy characterization. It also covers emerging technologies in energy-efficient design. Instructor Permission Required. Cross-list: COMP 518.
Course URL: www.ruf.rice.edu/~mobile/elec518/

ELEC 519 - NETWORK SYSTEMS ARCHITECTURE
Short Title: NETWORK SYSTEMS ARCHITECTURE
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 320 or ELEC 326
Description: Design and Implementation of network systems, including hardware and software architectures of network routers and servers. Students will design and implement wither the hardware or software components of a network system, depending on their experience and preferences. This course is suitable for students with expertise in either software or hardware. Cross-list: COMP 519. Recommended Prerequisite(s): COMP 221

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
Course URL: 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. 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
ELEC 523 - COMPUTER-AIDED DESIGN FOR VLSI
Short Title: COMPUTER-AIDED DESIGN FOR VLSI
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 topics in computer-aided design for VLSI: Logic synthesis and formal verification, timing analysis and optimization, technology mapping, logic and fault simulation, testing, and physical design will be covered. Relevant topics in algorithms and data structures, generic programming, and the C++ standard template library will also be covered. Cross-list: COMP 523.

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)

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
Prerequisite(s): COMP 425 or ELEC 425
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.

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: Credit cannot be earned for ELEC 527 and 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/

ELEC 529 - ADVANCED COMPUTER NETWORKS
Short Title: ADVANCED 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 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.

ELEC 530 - DETECTION THEORY
Short Title: DETECTION 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: Classic and modern methods of optimal decisions in communications and signal processing. Continuous- and discrete-time methods. Gaussian and non-Gaussian problems.
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  
Prerequisite(s): ELEC 432  
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: Credit cannot be earned for ELEC 534 and 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: Credit cannot be earned for ELEC 536 and 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 TOPICS IN COMPUTER NETWORKING  
Short Title: ADV TOP COMPUTER 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.
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:  
Prerequisite(s): ELEC 431 (may be taken concurrently)  
ELEC 430 or ELEC 551 or ELEC 535.

ELEC 540 - ADVANCED WIRELESS COMMUNICATIONS  
Short Title: ADVANCED WIRELESS COMM  
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:  
Prerequisite(s): (ELEC 342 or ELEC 332)

ELEC 541 - ERROR CORRECTING CODES  
Short Title: ERROR CORRECTING CODES  
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 430  
Description: Introductory course on error correcting codes. Topics covered include linear block codes, convolutional codes, turbo codes and LDPC codes.

ELEC 542 - THE APPLICATION OF VECTOR SPACE METHODS AND OTHER ADVANCED TECHNIQUES TO DSP  
Short Title: VECTOR SPACES AND 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  
Prerequisite(s): ELEC 431 (may be taken concurrently)  
Description: The course will introduce the application of vector space methods to digital signal processing. This includes topics such as representing a signal using basis expansions, Gram-Schmidt orthogonalization, linear inverse problems, gradient-descent, the use of regularization in approximation, and other advanced topics. The course may be taken in the same semester as ELEC 431.

ELEC 543 - HIGH-SPEED DSP AND ANALOG SYSTEM DESIGN  
Short Title: HS DSP & ANALOG SYS 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  
Prerequisite(s): (ELEC 342 or ELEC 332)  
Description: This course is intended for seniors and graduate students in Electrical Engineering. It covers practical aspects of high-speed DSP system design, and highlights system design and simulation challenges, and demonstrates common pitfalls and how to prevent them. Students learn how to design, simulate, and apply good high-speed and analog design practices that minimize both component and system noise and ensure system design success.

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 - THIN FILMS  
Short Title: THIN FILMS  
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: Deposition methods, structure, properties, performance and failure mechanisms of thin solid films for various applications. Deposition methods include sputtering, plating, evaporation and chemical vapor deposition. Material types include crystalline and amorphous metals as well as semiconductors and insulators. Applications are primarily in microelectronics; data storage; micro-electro-mechanical systems, wear and corrosion prevention and thermal barriers. NOTE: Not offered every year. Cross-list: MSNE 545.
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: Credit cannot be earned for ELEC 546 and 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: Credit cannot be earned for ELEC 548 and 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 mechanisms 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: Credit cannot be earned for ELEC 550 and ELEC 450.
ELEC 551 - DIGITAL COMMUNICATION
Short Title: DIGITAL COMMUNICATION
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: Course in digital communications, designed to prepare students for engineering work in high-tech industries and for graduate work in communications, signal processing, and computer systems. Covers basic concepts and useful tools for design and performance analysis of transmitters and receivers in the physical layer of a communication system. Additional coursework required beyond the undergraduate course requirements. Graduate/Undergraduate Equivalency: ELEC 430. Mutually Exclusive: Credit cannot be earned for ELEC 551 and 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: Credit cannot be earned for ELEC 552 and ELEC 421.
Course URL: 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: Credit cannot be earned for ELEC 553 and ELEC 424.
Course URL: www.ruf.rice.edu/~mobile/elec424/

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 caches. 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: Credit cannot be earned for ELEC 554 and 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: Credit cannot be earned for ELEC 555 and 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  
Cross-list: COMP 556. Graduate/Undergraduate Equivalency: ELEC 429.  
Mutually Exclusive: Credit cannot be earned for ELEC 556 and 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.  
Mutually Exclusive: Credit cannot be earned for ELEC 557 and ELEC 440.  
Course URL: 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: Credit cannot be earned for ELEC 558 and 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 coursework required beyond the undergraduate course requirements.  
Cross-list: BIOE 534.  
Graduate/Undergraduate Equivalency: ELEC 419.  
Mutually Exclusive: Credit cannot be earned for ELEC 559 and ELEC 419. Repeatable for Credit.  
Course URL: 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  
Prerequisite(s): ELEC 306 or PHYS 302  
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. Instructor Permission Required. Graduate/Undergraduate Equivalency: ELEC 460.  
Mutually Exclusive: Credit cannot be earned for ELEC 560 and 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: Credit cannot be earned for ELEC 562 and 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 photocatalysis. 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.
Course URL: www.ece.rice.edu/~daniel/569/569files.html

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 - NANOPHOTONIC DEVICES AND CIRCUITS
Short Title: PHOTONIC 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: An introduction to the theory and applications of nanophotonic devices built with high refractive index contrast. Topics include waveguides, couplers, resonators, photonic crystals and non-linear optical devices. Both analytical and numerical techniques for devices design will be discussed.

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: Credit cannot be earned for ELEC 575 and 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.

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: The course provides an introduction to concepts, methods, best practices, and theoretical foundations of machine learning. Topics covered include regression, classification, kernels, clustering, decision trees, ensemble learning, empirical risk minimization and regularization, and learning theory. Additional work is required for graduate students beyond the undergrad requirement. Graduate/Undergraduate Equivalency: ELEC 478. Mutually Exclusive: Credit cannot be earned for ELEC 578 and ELEC 478.

ELEC 581 - CARDIOVASCULAR AND RESPIRATORY SYSTEM DYNAMICS
Short Title: CARDIO - RESP SYSTEM DYNAMICS
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: Autonomous nervous system control of the cardiovascular and respiratory systems. Development of models of neuron and cardiac cell activity; models of ventricular and vascular system mechanics; models of pulmonary mechanics and gas transport. Includes a study of instrumentation and techniques used in the cardiac catheterization laboratory. Discussions of different types of ventricular assist devices is also included. The course serves as an introduction to engineering in cardiovascular and respiratory system diagnosis and critical care medicine. Cross-list: BIOE 581. Recommended Prerequisite(s): Knowledge of ordinary differential equations; electricity and magnetism, and solid mechanics form elementary physics; linear control theory and elementary physiology of the cardiovascular and respiratory systems.

ELEC 582 - PHYSIOLOGICAL CONTROL SYSTEMS
Short Title: PHYSIOLOGICAL CONTROL SYSTEMS
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: A study of the somatic and autonomic nervous system control of biological systems. Simulation methods, as well as, techniques common to linear and nonlinear control theory are used. Also included is an introduction to sensors and instrumentation techniques. Examples are taken from the cardiovascular, respiratory, and visual systems. Additional coursework required beyond the undergraduate course requirements. Cross-list: BIOE 582, Graduate/Undergraduate Equivalency: ELEC 482. Mutually Exclusive: Credit cannot be earned for ELEC 582 and ELEC 482.

ELEC 583 - COMPUTATIONAL NEUROSCIENCE AND NEURAL ENGINEERING
Short Title: COMP/NEUROSCIENCE/NEURAL ENGNR
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: An introduction to the anatomy and physiology of the brain. Includes basic electrophysiology of nerve and muscle. Develops mathematical models of neurons, synaptic transmission and natural neural networks. Leads to a discussion of neuromorphic circuits which can represent neuron and neural network behavior in silicon. Recommendation: Knowledge of electrical circuits, operational amplifier circuits and ordinary differential equations. Involves programming Matlab. Cross-list: BIOE 583, NEUR 583. Graduate/Undergraduate Equivalency: ELEC 481. Recommended Prerequisite(s): Knowledge of basic electrical and operational amplifier circuits; and ordinary differential equations. Mutually Exclusive: Credit cannot be earned for ELEC 583 and ELEC 481.

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. Graduate/Undergraduate Equivalency: ELEC 484. Mutually Exclusive: Credit cannot be earned for ELEC 584 and 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: Credit cannot be earned for ELEC 585 and 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: Credit cannot be earned for ELEC 586 and 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. Mutually Exclusive: Credit cannot be earned for ELEC 587 and 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: Credit cannot be earned for ELEC 588 and 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: Credit cannot be earned for ELEC 589 and 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: Theoretical and experimental investigations under staff direction. Instructor Permission Required. Repeatable for Credit.

ELEC 592 - GRADUATE ELECTRICAL ENGINEERING RESEARCH PROJECTS-GRADUATE ELECTRONICS PROJECTS
Short Title: GRAD ELEC ENG’G RESEARCH GE
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 594 - GRADUATE ELECTRICAL ENGINEERING RESEARCH PROJECTS-GRADUATE ELECTRONICS PROJECTS
Short Title: GRAD ELEC ENG’G RESEARCH GE
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 595 - GRADUATE RESEARCH
Short Title: GR RESEARCH
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 596 - FUNDAMENTALS OF MEDICAL IMAGING
Short Title: FUND MEDICAL IMAGING
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: Credit cannot be earned for ELEC 586 and ELEC 486.

ELEC 597 - GRADUATE RESEARCH PROJECTS
Short Title: GR RESEARCH 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 598 - GRADUATE RESEARCH PROJECTS
Short Title: GR RESEARCH 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 599 - GRADUATE RESEARCH PROJECTS-GRADUATE RESEARCH PROJECTS
Short Title: GRAD ELEC ENG’G RESEARCH
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 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 required for Graduate course. Cross-list: COMP 598, MECH 598. Graduate/Undergraduate Equivalency: ELEC 498. Mutually Exclusive: Credit cannot be earned for ELEC 598 and ELEC 498.

ELEC 599 - FIRST YEAR GRAD STUDENT PROJECTS
Short Title: 1ST YEAR GRAD STUDENT PROJECT
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
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/NMLcourse2.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 TOPICS IN SIGNAL PROCESSING AND MACHINE LEARNING
Short Title: TOPICS-SIGNAL PROCESSING & 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
Prerequisite(s): ELEC 531 and ELEC 533
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) stepizes 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.
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 638 - INFO-GAP THEORY AND ITS APPLICATIONS
Short Title: INFO-GAP THEORY & ITS APPS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Course Level: Graduate

ELEC 677 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Electrical & Computer Eng.
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Laboratory, Lecture, Seminar, Lecture/Laboratory
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 681 - FUNDAMENTALS OF MACHINE LEARNING
Short Title: FUNDAMENTALS 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 examines the fundamentals of machine learning, including supervised learning, unsupervised learning, and reinforcement learning. This course will provide the student with the formal concepts and the basic intuition for the different topics of machine learning, from artificial neural networks to value function approximation. Because of the shared problems of machine learning, statistical inference, and signal processing, a focus of the course will be on sharing solutions, e.g., dimensionality reduction, of these three fields. Repeatable for Credit.

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 state 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/

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 Hour: 1
Restrictions: Enrollment is limited to Graduate level students. Enrollment limited to students in a Master of Electrical Eng degree.
Course Level: Graduate
Description: The Professional Masters Seminar Series presents a combination of seminars on emerging research topics in the many areas of ECE and industry-focused professional development. This course includes attendance and reports based on the seminars, colloquia, and distinguished lectures held each semester. Repeatable for Credit.

ELEC 699 - FRONTIERS OF ELECTRICAL AND COMPUTER ENGINEERING
Short Title: FRONTIERS OF ECE
Department: Electrical & Computer Eng.
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to students with a major in Electrical & Computer Eng.. Enrollment is limited to Graduate level students. Enrollment limited to students in a Doctor of Philosophy or Master of 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 Engineering degree: BSEE

Undergraduate Major Description and Code
• Major in Electrical Engineering (both BA and BSEE degrees): ELEG

Undergraduate Major Areas of Specialization

Descriptions and Attribute Codes*
• Area of Specialization in Computer Engineering (both BA and BSEE degrees): EECE
• Area of Specialization in Data Science/Systems (both BA and BSEE degrees): EEDS
• Area of Specialization in Neuroengineering (both BA and BSEE degrees): EENE
• Area of Specialization in Photonics, Electronics, and Nano-devices (both BA and BSEE degrees): EEPH

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.

Graduate Degree Descriptions and Codes
• Master of Electrical Engineering degree: MEE
• Master of Science degree: MS
• Doctor of Philosophy degree: PhD

Graduate Degree Program Descriptions and Codes
• Degree Program in Electrical Engineering (MEE degree): ELEG
• Degree Program in Electrical and Computer Engineering (both MS and PhD degrees): ELEC

CIP Code and Description ¹
• ELEC Major/Program: CIP Code/Title: 14.1001 - Electrical and Electronics Engineering
• ELEG Major/Program: CIP Code/Title: 14.1001 - Electrical and Electronics 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) 2010 Codes and Descriptions from the National Center for Education Statistics: https://nces.ed.gov/ipeds/cipcode/