

## So you want to be an electrical engineer...

Congratulations! You've chosen wisely. As an electrical engineer, you will acquire an incredibly broad skillset, learning to build circuits and systems, design computer hardware and software, manipulate data and information, invent new devices and materials, and utilize optics and photonics, all in service of the grand challenges facing the world in the coming century. Our curriculum encourages students to apply their knowledge in so many ways, including biomedical engineering, energy and the environment, information security, machine learning, high-performance and quantum computing, robotics and cyber-physical systems, and countless more. We're constantly amazed at the breadth of innovative paths our students take when they graduate. We know we'll be amazed at what you do too!

Over your six semesters in our department, you'll need to take 14 courses to earn your degree – six required ELE courses, three technical electives in your chosen area of concentration, one elective outside your concentration to provide breadth, your thesis (which counts as two courses), an upper level math course and an engineering science course. That gives you an excellent EE education, yet leaves nearly half your schedule free to explore all that Princeton has to offer. Here's a brief look at what's in store – you can get all the nitty gritty details in our handbook.

### Sophomore Year Requirements

**ELE 201: Information Signals.** Signals that carry information play a central role in technology and engineering — signals ranging from sound and images to sensors, radar, communication, MRI, ultrasound, touch-screens, GPS, and robotic control. You'll learn the mathematical tools to analyze, manipulate, dissect, and preserve information signals, and you'll apply these tools to design projects including a "Shazam" music identification system.

**ELE 203: Electronic Circuit Design, Analysis and Implementation.** This is your first introduction to how circuits work. You'll learn how to analyze circuits and, more importantly, to design and implement circuits. You'll get your first taste of biomedical engineering as you build a brain-machine interface that can display your current state of relaxation.

**ELE 206: Contemporary Logic Design.** This is your first introduction to digital logic that underpins modern computing. You'll learn to piece this logic together to design computer systems, and will build a fully-functioning computer using programmable logic!

**ELE 208: Electronic and Photonic Devices.** This course teaches you how semiconductor devices work, including transistors, lasers and solar cells. You'll also learn how to do micro- and nano-fabrication, and will go into the cleanroom to fabricate your own lasers, integrated circuits, and solar cells!

## Junior Year

**ELE 301: Designing Real Systems.** Junior year is about synthesis. This course will teach you how to bring the various elements from the sophomore year together to design complex systems. You'll learn about signals and noise, feedback and control, and embedded computing. You'll get an Android tablet and will write apps that can interact with hardware you build to map out air quality in the EQuad.

**ELE 302: Building Real Systems.** The amazing carlab! You'll spend the first half of the semester getting to know and love your car, and learning how to build a complex system. Your car will use a digital camera to drive autonomously at a constant speed. In the second half of the class, you use the car as a platform to do anything you want – drift parallel parking, play soccer, catch a ball, map out the room – you pick the sensors and the platforms and do something incredible!

## Senior Year

**Thesis! (ELE 497/498).** All electrical engineering students do a two semester thesis as the culmination of their Princeton education. This is widely described as one of the most rewarding experiences at Princeton, and provides a chance to work closely with faculty to create something entirely new.

We have two flavors of thesis. Many students choose to work with a faculty member doing research in their area of expertise. This gives you a chance to learn and contribute to the cutting edge of an enormous variety of fields. Past theses have included researching a non-invasive glucose monitor, a trace gas sensing system, large area electronics, quantum computing, exoscale computing, privacy and security, big data and MOOCs, and machine learning.

We also have student-driven projects, where students come up with an idea that they want to implement. Students work under the mentorship of a faculty member, often outside of their area of expertise. Past student driven projects have included a drone-based avalanche rescue system, a multi-drone 3D cinematography system, a hybrid robot capable of switching between wheeled and legged operation, an origami folding robot, and a drone capable of flying and submerging underwater. Students often work in pairs or teams, often collaborating with students from other departments.

## General SEAS Requirements

**Upper Level Math.** Students take one upper level math course of their choosing. Most ELE students take either differential equations (MAE 305) or probability (ORF309), but you can take any math course at the 300 level or above.

**Engineering Science.** Students take one course in a non-ELE SEAS discipline that is not a math course. This can be in any SEAS department, and often fills a cross-disciplinary interest. Most students fill this with COS 217 or COS 226, but there are countless options – a full list of common courses is in the handbook.

## Areas of Concentration

Beyond our required courses, you'll take three courses in one area of concentration, and one breadth course outside your concentration. Concentrations cover core areas within EE and major applications, and are often interdisciplinary – one of your three concentration courses can be outside of ELE. We have ten areas of concentration:

**Computer Systems.** Unlock the secrets of how computing works at all levels of abstraction, from transistors to gates to bits to computer architecture to programs to algorithms. In this concentration, you will gain the knowledge to analyze and build complete computing systems which is at the heart of and the main driver of the great advances built on top of computing. Faster and more efficient computing systems have and will continue to drive great advances in our society from better entertainment systems to better rocket design (fluid flow modeling) to unlocking the mysteries of the human genome.

**Circuits and Systems.** Circuit-design is the business of using the physics of devices, connected into networks to create functions of high value to us. Modern circuits represent some of the most complex man-made systems, and they deliver functions of some of the highest importance to society. The concentration in Circuits and Systems will prepare you to push the frontier, with an emphasis on the biggest challenges faced in industry and academic research today.

**Data and Information.** How can HD video be compressed and sent over an LTE network to your phone? How are medical images acquired and analyzed to diagnose diseases? And how does Netflix learn about your taste on movies? These are some of the questions that underlie the concentration in data and information. Learn the principles and underlying theories exemplified by image and video processing, machine learning, data transmission and compression, information theory and networking.

**Electronic Devices and Materials.** New materials and devices lie at the heart of modern technology. Learn how semiconductor materials and devices work, and how to fabricate devices and characterize materials. Apply your learning to explore large area electronics, novel sensor networks, solar cells, and medical diagnostic devices.

**Optics and Photonics.** Light provides a powerful tool for imaging, sensing and communication. Learn how to generate and detect light and how lasers work, and apply your learning to biomedical imaging, photonic communications, and environmental sensing.

**Quantum Information and Applied Physics.** What kind of computers could you build if you could completely harness the bizarre laws of quantum mechanics? What kind of sensors become possible? Ones that are fundamentally different and seemingly impossible compared with what we have today, going well-beyond fundamental classical limits! Learn how they work and apply your learning to build real quantum systems!

**Biomedical Engineering.** EE provides an incredible toolbox for understanding and manipulating biological systems. Learn to build and understand machine-brain interfaces, implantable electronics, biomedical imaging systems, and non-invasive optical probes, and to use data science to understand the brain and biological signals.

**Security and Privacy.** The security and privacy concentration aims to embed trust and resilience in our computing and communication infrastructure, including emerging paradigms based on Internet of Things, cyber-physical systems, social networks, connected cars and mobile, medical and wearable devices. The concentration includes the design of secure and resilient protocols that thwart sophisticated attackers, as well as approaches to protect the privacy of user data and communications.

**Robotics and Cyber-physical systems.** Electronic systems of the future will not only be aware of their surroundings, but capable of high-level planning and responses based on complex societal needs. Robotics and cyber-physical systems bring together sensors and actuators, computational subsystems, algorithms for inference and control, mathematical foundations for guaranteeing behaviors, and full system design and deployment. The concentration in Robotics and Cyber-physical Systems will prepare you in these aspects, looking forward to intelligent systems of the future.

**Energy and the Environment.** Electrical engineering provides a powerful toolbox for addressing global issues with energy and the environment. Learn how alternate energy sources work, how to design low-power electronics, how to manage and optimize a smart grid, and how to develop new environmental monitoring technology.

## Slingshot Fund

What would you do if money were not an issue? Do you have a great idea that you would love to try out? A product you want to develop? A company you might want to launch? An internship you wish to pursue?

The Department of Electrical Engineering is pleased to announce the Stephen C. Johnson Slingshot Fund for Innovation, a prize to help launch your dreams and make them a reality. We will award between one and five grants a year, totaling up to \$50,000, so funding for your idea could be substantial. This is not just another call for senior thesis or independent work funding, though that is one possibility.

This is a call to think bold and dream big, available to all electrical engineering students. We want to enable you to do great things, and proposals will be judged based on creativity, boldness, and feasibility.

## ELE Undergraduate Concentrations: the Details

### Circuits and Systems

Required:

ELE304 Electronic Circuits: Devices to ICs (S)

Two courses from:

- ELE341 Solid State Devices (F)
- COS/ELE375 Computer Architecture and Organization (S)
- ELE382 Statistical Signal Processing (F)
- ELE461\* Design with Nanotechnologies
- ELE462 Design of VLSI (F)
- ELE464 Embedded Computing (S)
- ELE475 Computer Architecture (S)
- ELE481 Power Electronics (S)
- ELE482 Digital Signal Processing (S)

\* ELE461 no longer offered, but past students may use it for this concentration

### Data and Information

Required:

ORF309\* Probability and Stochastic Systems (F & S)

Two courses from:

- ELE364\*\* Machine Learning for Predictive Data Analysis (F)
- ELE381 Networks: Friends, Money and Bytes (F)
- ELE382 Statistical Signal Processing (F)
- ELE477\*\* Kernel Methods in Machine Learning (F)
- ELE482 Digital Signal Processing (S)
- ELE486 Transmission and Compression of Information (S)
- ELE488\*\*\*Image Processing
- ELE435\*\* Machine Learning and Pattern Recognition (F)
- COS324\*\*Introduction to Machine Learning (F)
- COS402 \*\*Artificial Intelligence
- COS424\*\* Fundamentals of Machine Learning (S)
- COS429 Computer Vision (F)

\*To concentrate in Data and Information, a student must take ORF309. It can be used to fulfill the concentration or upper level math requirement, but not both

\*\*Only one Machine Learning course may be applied to this concentration

\*\*\*ELE488 no longer offered, but past students may use it for this concentration

### Computer Systems

Required:

COS/ELE375 Computer Architecture and Organization (S)

Two courses from:

- ELE461\* Design with Nanotechnologies
- ELE462 Design of VLSI (F)
- ELE464 Embedded Computing (S)
- ELE470 Smartphone Security and Architecture (F)
- ELE475 Computer Architecture (S)
- COS318 Operating Systems (F)
- COS320 Compiling Techniques (S)
- COS461 Computer Networks (S)

\* No longer offered, but past students may use it for this concentration

### Security and Privacy

Required:

COS/ELE432 Information Security (F & S)

Two courses from:

- COS/ELE375 Computer Architecture and Organization (S)
- ELE364\*\* Machine Learning for Predictive Data Analysis (F)
- ELE435\*\* Machine Learning and Pattern Recognition (F)
- ELE464 Embedded Computing (S)
- ELE470 Smartphone Security and Architecture (F)
- COS324\*\*Introduction to Machine Learning (F)
- COS402\*\*Artificial Intelligence
- COS424\*\* Fundamentals of Machine Learning (S)
- COS433 Cryptography (S)
- COS461 Computer Networks (S)

\*\* Only one Machine Learning course may be applied towards this concentration

### Electronic Devices and Materials

Required:

ELE341 Solid State Devices (F)

Two courses from:

- ELE304\* Electronic Circuits: Devices to ICs (S)
- ELE342 Principles of Quantum Engineering (S)
- ELE431 Solar Energy Conversion (F)
- ELE441 Solid-State Physics I (F)
- ELE481\* Power Electronics (S)
- MAE324 Structure and Properties of Materials (F)
- MAE424 Energy Storage Systems (S)
- MSE301 Materials Science and Engineering (S)
- MSE302 Laboratory Techniques in Materials Science (F)
- MSE505 Characterization of Materials (S)

\* Only one circuits (304 or 481) course may be applied towards this concentration

### Biomedical Engineering

Three courses from:

- ELE304 Electronic Circuits: Devices to ICs (S)
- ELE452 Biomedical Imaging (F)
- ELE455\* Mid-IR Tech. for Health & Environment
- ELE480 fMRI Decoding: Reading Minds (F)
- ELE488\* Image Processing
- COS429 Computer Vision (F)
- COS455 Genomics & Computational Molecular Biology (F)
- MAE344 Biomechanics and Biomaterials (S)
- NEU427 Systems Neuroscience (S)
- NEU437 Computational Neuroscience (S)

\*ELE455 and 488 no longer offered. Past students may use it for this concentration

### **Robotics and Cyber-physical Systems**

Three courses from:

ELE304 Electronic Circuits: Devices to ICs (S)  
COS/ELE375 Computer Architecture and Organization (S)  
ELE364\*\* Machine Learning for Predictive Data Analysis (F)  
ELE435\*\* Machine Learning and Pattern Recognition (F)  
ELE464 Embedded Computing (S)  
ELE488\*\*\* Image Processing  
COS324\*\* Introduction to Machine Learning (F)  
COS402\*\* Artificial Intelligence  
COS429 Computer Vision (F)  
MAE345 Robotics and Intelligent Systems (F)  
MAE433 Automatic Control Systems (F)

\*\* Only one Machine Learning course may be used for this concentration

\*\*\* No longer offered, but past students may use it for this concentration

### **Quantum Information and Applied Physics**

ELE342\*\* Principles of Quantum Engineering (S)

Two courses from:

ELE396 Introduction to Quantum Computing (F)  
ELE441 Solid-State Physics I (F)  
ELE453 Optical Electronics (F)  
ELE456 Quantum Optics (S)  
ELE568 Implementations of Quantum Information (F)

\*\* PHY208 and 305 can be taken in lieu of ELE342, but are counted as one course for the concentration requirement

### **Optics and Photonics**

Required:

ELE 351 Electromagnetic Field Theory and Optics (S)

Two courses from:

ELE 342 Principles of Quantum Engineering (S)  
ELE 452 Biomedical Imaging (F)  
ELE 453 Optical Electronics (F)  
ELE 454 Photonics and Light Wave Communications (S)  
ELE455\* Mid--IR Tech. for Health & Environment  
ELE 456 Quantum Optics (S)  
MAE521 Optics and Lasers (F)

\*ELE455 no longer offered. Past students may use it for this concentration

### **Energy and the Environment**

Three courses from:

ELE 341 Solid State Devices (F)  
ELE 431 Solar Energy Conversion (F)  
ELE455\* Mid--IR Tech. for Health & Environment  
ELE481 Power Electronics (S)  
ELE 557 Solar Cells: Physics, Materials, and Technology (F)  
MAE 424 Energy Storage Systems (S)

\*ELE455 no longer offered. Past students may use it for this concentration