Electrical, Computer & Energy Engineering
UNIVERSITY OF COLORADO **BOULDER**

University of Colorado Boulder Department of Electrical, Computer and Energy Engineering

ECEE Help Guide 2016-17

The Complete Guide to Your Undergraduate Experience

Contents

Welcome to the ECEE Department!

We are pleased you have chosen the Electrical, Computer and Energy Engineering Department to help pursue your career goals. The department offers two baccalaureate degrees, a B.S. in Electrical Engineering and a B.S. in Electrical and Computer Engineering. Both degree programs are accredited by the Engineering Accreditation Commission of ABET, www.abet.org.

This HELP! Guide has been written to assist you in understanding department curriculum requirements and regulations. You should also be familiar with the Advising Guides published by the Dean's Office. In cases where department rules differ from those of the College, the department rules supersede. You are responsible for knowing both sets of rules.

Because the curriculum is continually changing, you are expected to follow the curriculum in effect when you entered the program, as reflected in this guide.

The ECEE faculty and staff are here to help you with whatever problems you may encounter along the way. You should become familiar with the people listed in the box on this page.

As a freshman, you should see your academic advisor, assigned by your last name. It is a requirement to meet with your advisor prior to registration every semester.

When you have questions about curriculum requirements, department regulations, course sequences, etc., contact the Undergraduate Advisors.

If you have technical questions about course content, or the desirability of certain courses in the marketplace, career advice, etc. you may be referred to a faculty member.

When rearranging courses to fit your particular needs, be sure to consider how postponing a course that is a prerequisite to others will affect the remainder of your schedule. You will find that some courses may be moved without penalty, while postponing others will delay your graduation by a semester or more. As you will see in the curriculum guide, many courses are only offered once an academic year.

College is very different from high school. You are expected to take much more initiative in such things as arranging your own schedule, gathering information, and seeking help when needed.

If you find you need help – whether for academic or personal difficulties – there are many resources available on campus. Please come see us before a problem becomes serious. If we can't help you solve your problem, we can refer you to someone who can.

We look forward to working with you along your academic journey.

Best Wishes,

Beth and Maureen
Academic Advisors

Electrical, Computer & Energy Engineering Advising Contacts

- Associate Chair of Undergraduate Education: Prof. Sean Shaheen (ECOT 256, 303-492-9627)
- Academic Advisors: Beth Curtis (ECEE 1B61, 3-492-3511) & Maureen Craig (ECEE 1B20, 3-735-7298)
- Schedule appointments online at www.colorado.edu/mycuhub.
- Course information and Career Advisors: Any ECEE faculty member
- Career Advising outside the department: Career Services Office (Center for Community N352, www.colorado.edu/engineering/academics/career-services)

Mission and Objectives for the Undergraduate Programs

Department Overview

The department was founded in the 1890s, in the earliest days of the College of Engineering. Today it has 39 tenured and tenure-track professors, 10 professors with secondary appointments to the department, three research professors and over 10 adjunct professors, instructors and lecturers.

Two of our faculty are members of the National Academy of Engineering, 14 are Institute of Electrical and Electronics Engineers (IEEE) Fellows, three are Optical Society of America Fellows and eight are members of Eta Kappa Nu, the national Electrical and Computer Engineering honors society.

Our faculty are active in research, with research expenditures totaling about $6.8 million annually. Our research is concentrated in 10 different areas, from biomedical engineering to VLSI/CAD.

Mission Statement

The Department of Electrical, Computer and Energy Engineering at the University of Colorado Boulder is the premier undergraduate and graduate EE/ECE program in Colorado and all adjoining states, as measured by reputation, national rankings and department size. The primary mission of the ECEE Department is:

- To provide relevant and highly-respected undergraduate EE and ECE degree programs to on-campus students,
- To provide excellent graduate degree programs in electrical and computer engineering,
- To advance industry in the state of Colorado and the nation, as well as the accumulated knowledge of humanity, through our high quality research programs, and
- To use our on-campus educational activities to provide high-quality continuing education programs for off-campus students.

It is widely acknowledged that an engineering undergraduate education is a strong foundation for a successful career in many different disciplines including, of course, engineering, but additionally in management, business, law, medicine and even politics. While our primary focus is on engineering careers we are pleased when our graduates take their foundations in analysis, problem solving and understanding of complex systems into diverse careers.

Our curriculum is designed to help our graduates become viable in a globally competitive work environment. Our graduates are able to establish a portfolio of up-to-date skills, abilities, and accomplishments that distinguish them from the competition. Further, the core disciplines and intellectual skills they develop form the framework for a successful career in an environment where the state of practice advances rapidly.

Employment Opportunities

According to the Bureau of Labor Statistics, electrical, electronics and computer engineers make up the largest branch of engineering. They are found in professional, scientific and technical services firms, government agencies, manufacturers of computer and electronic products and machinery, wholesale trade, communications and utilities firms. On the CU-Boulder campus, recruiters request interviews with electrical engineering and computer engineering graduates in numbers several times those of other majors, even other engineering majors.

Our graduates go to work for both large engineering companies (Lockheed Martin, IBM, Agilent, Hewlett Packard, Xilinx, Intel, Northrup Grumman, Ball Aerospace, Maxtor, Seagate, Sun Mircosystems, National Instruments, Texas Instruments, Apple Computers, Micron) and local firms such as SpectraLogic and Level 3 Communications. Some of our graduates go on to graduate school and occasionally our graduates start their own companies.

Electrical, Computer and Energy Engineering Disciplines

Biomedical & Neural Engineering

Biomedical engineering is concerned with the development and manufacture of prostheses, medical devices, diagnostic devices, drugs, and other therapies. It is more concerned with biological, safety, and regulatory issues than other disciplines in engineering. Our faculty are currently pursuing research in bioelectromagnetics which involves the use of electromagnetic fields to probe biological functions, MRI, and other diagnostic tools.

Communications & Signal Processing

Communication engineering and information theory are concerned with the efficient representation and reliable transmission and/or storage of information. Communications engineers develop: digital audio, pattern recognition, speech processing and recognition, audio and image compression, medical imaging, digital filtering, and more.

Computer Engineering

A computer engineer is an electrical engineer with a focus on digital logic systems, and less emphasis on radio frequency or power electronics. From a computer science perspective, a computer engineer is a software architect with a focus on the interaction between software programs and the underlying hardware components.

Dynamics and Controls

Control techniques are used whenever some quantity, such as speed, temperature, or force must be made to behave in some desirable way over time. Currently, our dynamics and controls group are working on diverse problems such as developing controllers for aircraft, spacecraft, information storage systems, human-machine interfaces, manufacturing processes, and power systems.

Electromagnetics, RF and Microwaves

This specialty area is concerned with the use of the electromagnetic spectrum. In particular, our faculty focus on current commercial and military needs such as active circuits, antennas for communications and radar, theoretical and numerical techniques for analysis of high-frequency circuits and antennas, and artificial electromagnetic materials.

Nanostructures and Devices

Solid-state devices form the basis of integrated circuits, which have a variety of electronic, optoelectronic, and magnetic applications. The research in this field is concerned with the design, fabrication, and characterization of novel materials and devices with sub-micron feature sizes. Their potential applications include very high-speed devices, optical sources and detectors, optoelectronic components and all-optical devices. The design and fabrication of devices and integrated circuits are inextricably related to device physics, solid-state materials, and sophisticated processing techniques.

Optics and Photonics

This area emphasizes the design, fabrication and characterization of materials, devices and systems for the generation, transmission, amplification, detection and processing of light signals. These are enabling and pervasive technologies applied in fields like communications, sensing, bio-medical instrumentation, consumer electronics and defense.

Power Electronics and Renewable Energy Systems

Power electronics is the technology associated with the efficient conversion, control and conditioning of electronic power by static means from its available input form into the desired electrical output form. In contrast to electronic systems concerned with transmission and processing of signals and data, in power electronics substantial amounts of electrical energy are processed.

VLSI/CAD

Very Large Scale Integration – a term applied to most modern integrated circuits that comprise hundreds to thousands to millions of individual components. Research in this area works toward developing new algorithms and design methodologies to efficiently design VLSI integrated circuits.

Program Objectives for BS in Electrical Engineering

1. EE-1: Graduates will be situated in growing careers involving the design, development or support of electrical or electronic systems, devices, instruments, or products, or will be successfully pursuing an advanced degree.

   Graduates attaining the EE degree will have comprehensive knowledge and experience in the concepts and design of electrical and electronic devices, circuits, and systems. This is achieved through a sequence of required courses in these areas, culminating in a major design project incorporating realistic engineering constraints. Moreover, graduates will have advanced, specialized knowledge and skills in elective areas such as communications and digital signal processing, control systems, analog and digital integrated circuit design, semiconductor devices and optoelectronics electromagnetics and wireless systems, power electronics and renewable energy, bioelectronics, and digital systems.

   EE graduates will have attained other professional skills that will be useful throughout their careers, including verbal and written communication and the ability to function on multi-disciplinary teams.

   The EE curriculum is rich in laboratory work. EE graduates will have achieved extensive practical experience in the laboratory techniques, tools, and skills that provide a bridge between theory and practice.

2. EE-2: Graduates will have advanced in professional standing based on their technical accomplishments, and will have accumulated additional technical expertise to remain globally competitive.

   EE graduates experience a curriculum that contains a broad core of classes focused on mathematical and physical principles that are fundamental to the field of electrical engineering. Hence, they understand the physical and mathematical principles underlying electrical and electronic technology, and are able to analyze and solve electrical engineering problems using this knowledge. In addition to basic classes in mathematics, science, and computing, the EE curriculum includes a sequence of courses in analog and digital electronic circuits and systems, and electromagnetic fields.

3. EE-3: Graduates will have demonstrated professional and personal leadership and growth.

   To lay the foundation for a long career in a rapidly changing field, a broad background of fundamental knowledge is required. This is achieved in the EE curriculum through a sequence of required classes in mathematics, physics, chemistry, and the EE core. In addition, the graduate must be capable of lifelong learning; this is taught through assignments and projects that require independent research and study.

   The curriculum includes a significant component of electives in the humanities and social sciences. EE graduates will have knowledge of the broader contemporary issues that impact engineering solutions in a global and societal context. They will have the verbal and written communications skills necessary for a successful career in industry or academia. Graduates also understand the meaning and importance of professional and ethical responsibility.

Program Objectives for BS in Electrical & Computer Engineering

1. ECE-1: Graduates will be situated in growing careers involving the design, development or support of electrical, electronic, and computer hardware and software systems, software engineering, devices instruments, or products, or will be successfully pursuing an advanced degree.

   Graduates attaining the ECE degree will have comprehensive knowledge and experience in the concepts and design of electrical, electronic, and computer devices, circuits, and systems. Besides emphasizing computer hardware and software, the ECE curriculum also emphasizes design, integration, implementation, and application of computer systems, as well as experience in software development. This is achieved through a sequence of required courses in these areas, culminating in a major design project incorporating realistic engineering constraints. The curriculum also provides opportunities for specialization in areas such as compiler design, embedded systems, software engineering, and VLSI design, as well as in the electrical engineering specialties.

   ECE graduates will have attained other professional skills that will be useful throughout their careers, including verbal and written communication and the ability to function on multi-disciplinary teams.

   The ECE curriculum is rich in laboratory work. ECE graduates will have achieved extensive practical experience in the laboratory techniques, tools, and skills that provide a bridge between theory and practice.

2. ECE-2: Graduates will have advanced in professional standing based on their technical accomplishments and will have accumulated additional technical expertise to remain globally competitive.

   ECE graduates experience a curriculum that contains a broad core of classes focused on mathematical and physical principles that are fundamental to the fields of electrical and computer engineering. Hence, they understand the physical and mathematical principles underlying electrical and electronic technology and computer systems, and are able to analyze and solve electrical and computer engineering problems using this knowledge. In addition to basic classes in mathematics, science, and computing, the ECE curriculum includes a sequence of courses in analog and digital electronic circuits and systems, electromagnetic fields, probability, computer software, and computer design and architecture.

3. ECE-3: Graduates will have demonstrated professional and personal leadership and growth.

   To lay the foundation of a long career in a rapidly changing field, a broad background of fundamental knowledge is required. This is achieved in the ECE curriculum through a sequence of required classes in mathematics, physics, chemistry, and the ECE core. In addition, the graduate must be capable of lifelong learning; this is taught through assignments and projects that require independent research and study.

   The curriculum includes a significant component of electives in the humanities and social sciences. ECE graduates will have knowledge of the broader contemporary issues that impact engineering solutions in a global and societal context. They will have the verbal and written communications skills necessary for a successful career in industry or academia. Graduates also understand the meaning and importance of professional and ethical responsibility.

Basic Program Requirements

Electrical Engineering Curriculum

Key: F = course offered only in the fall semester; S = course offered only in the spring semester; SM = course offered in summer; D = undergraduate and graduate course

Math
(19 hours, minimum grade of C- required)

Course Name	Hours	Notes
APPM 1350 Calculus 1 for Engineers	4	
APPM 1360 Calculus 2 for Engineers	4	
APPM 2350 Calculus 3 for Engineers	4	
APPM 2360 Diff Equations w/ Linear Algebra	4	
ECEN 3810 Probability (May substitute APPM 3570)	3	F

Physics (9 hours)

PHYS 1110 Gen Physics 1	4	
PHYS 1120 Gen Physics 2	4	
PHYS 1140 Experimental Physics 1	1	

Freshman Elective (3-5 hours, choose one)

ECEN 1400 Intro to Digital/Analog Elect.	3	
GEEN 1400 Freshman Projects (or Freshman Projects from other engr. dept.)	3	
CHEM 1131 General Chemistry 2	5	AP/ transfer

Freshman Seminar (1 hour, choose one)

ECEN 1100 Freshman Seminar	1	
GEEN 1500 Intro to Engineering (or Freshman Seminar from other engr. dept.)	1	

General Science Elective
(3-5 hours, choose one)

Course Name	Hours	Notes
PHYS 2130 General Physics 3	3	
MCEN 3012 Thermodynamics	3	
EBIO 1210 General Biology 1 (lab optional)	3	
MCDB 1150 Intro to Molecular Biology	3	
IPHY 3410 Intro to Human Anatomy	3	
CHEN 1211 General Chemistry for Engineers (with 1221 lab)	5	

Computer Programming (4 hours)

ECEN 1310 C Programming for EE/ECE (May substitute CSCI 1300 for transfers only)	4	

Sophomore Electives (6 hours, choose two)

ECEN 2410 Renewable Energy	3	F
ECEN 2420 Electronics for Wireless Communication	3	S
ECEN 2440 Application of Embedded Systems (also as ECEN 2020)	3	F

Electrical Engineering Core (18 hours)

Course Name	Hours	Notes
ECEN 2250 Intro to Circuits & Electronics	3	
ECEN 2260 Circuits as Systems	3	
ECEN 2270 Electronics Design Lab	3	
ECEN 2350 Digital Logic	3	
ECEN 3350 Programming of Digital Systems	3	
ECEN 3360 Digital Design Lab	3	

Advanced Analog Core (9 hours)

ECEN 3250 Microelectronics	3	
ECEN 3300 Linear Systems	3	
ECEN 3400 Fields	3	

Track Courses
(12 hours, must fulfill requirements for two "tracks," details on page XX)

ECEN 4011 Design of Implantable Devices (even yrs)	3	S, D
ECEN 4021 Engineering Apps in Medicine (odd yrs)	3	S, D
ECEN 4242 Communication Theory	3	F
ECEN 4652 Communication Lab	3	S, D
ECEN 4532 Digital Signal Processing Lab	3	S, D
ECEN 4632 Intro to Digital Filtering	3	F
ECEN 3410 EM Waves & Transmissions	3	S
ECEN 4634 Microwave/RF Lab	3	F, D
ECEN 3320 Semiconductor Devices	3	S
ECEN 4555 Prin of Energy Systems/Devices	3	F, D
ECEN 4015 Photovoltaic Devices	3	F

Track Courses (cont.)

Course Name	Hours	Notes
ECEN 4606 Undergrad Optics Lab	3	varies
ECEN 4616 Optoelectronic System Design	3	varies
ECEN 4106 Photonics	3	varies
ECEN 4116 Intro to Optical Communication	3	varies
ECEN 3170 Electromagnetic Energy Conversion 1	3	F
ECEN 4167 Electromagnetic Energy Conversion 2	3	S
ECEN 4797 Intro to Power Electronics	3	F, D
ECEN 4517 Renewable Power Electronics Lab	3	S, D
ECEN 4138 Control Systems Analysis	3	F, D
ECEN 4638 Controls Lab	3	S

Technical Electives
(variable, typically 6-12 hours)

Use other 3000/4000 technical courses in ECEN, other engineering departments, APPM, MATH, PHYS to complete 128 hour requirement.

Non-track ECEN Technical Electives for EE

ECEN 4593 Computer Organization	3	S
ECEN 4653 Real-Time Digital Media Systems	3	S
ECEN 4224 High-Speed Digital Design	3	S, D
ECEN 4324 Fundamentals of Microsystem Packaging	3	F, D
ECEN 4--- Selected Special Topics	3	

May also use 3000/4000 level technical courses in other engineering departments, APPM, MATH and PHYS. In addition, up to 6 hrs EMEN/Business/ECON may be applied. See rules on page XX. Check with advisor for applicability.

Capstone Design Lab
(6 hours, minimum grade of C- required)

Course Name	Hours	Notes
ECEN 4610 Capstone Laboratory, Part 1	3	F
ECEN 4620 Capstone Laboratory, Part 2	3	S

Humanities/Social Sciences (21 hours)

Course Name	Hours	Notes
1000/2000 A&S Core Lower Division	12	
3000/4000 A&S Core Upper Division	6	
WRTG Approved upper-division writing	3	

(see page 20 for course selection requirements)

Free Electives (6 hours maximum)
Student choice of courses

Key to Sample Schedules (Pages 13 and 16)

Semester credit hours, General Science Elective hours and Technical Elective hours may vary over semesters. Total hours taken towards the degree must equal at least 128. See page 17 for prerequisites for Capstone Lab 1 & 2. Minimum grade required in both courses is C-.

* See the previous page for approved substitutes.

** See the previous page for General Science Electives and Technical Electives.

Sample Schedule for Electrical Engineering Program

Freshman Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
APPM 1350	Calculus 1	4	APPM 1360	Calculus 2	4
PHYS 1110	Physics 1	4	PHYS 1120	Physics 2	4
ECEN 1100	Freshman Seminar (F)	1	PHYS 1140	Experimental Physics	1
ECEN 1400	Freshman Elective*	3	ECEN 1310	C Programming for EE/ECE*	4
	Humanities/Social Sciences	3		Humanities/Social Sciences	3
	TOTAL CREDIT HOURS	15		TOTAL CREDIT HOURS	16

Sophomore Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
APPM 2360	Diff. Eq. with Linear Algebra	4	APPM 2350	Calculus 3	4
ECEN 24--	Sophomore Elective 1	3	ECEN 24--	Sophomore Elective 2	3
ECEN 2250	Intro to Circuits & Electronics	3	ECEN 2260	Circuits as Systems	3
ECEN 2350	Digital Logic	3	ECEN 2270	Electronics Design Lab	3
	Humanities & Social Sciences	3		General Science Elective**	3
	TOTAL CREDIT HOURS	16		TOTAL CREDIT HOURS	16

Junior Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
ECEN 3350	Programming of Digital Systems	3	ECEN 3360	Digital Design Lab	3
ECEN 3810	Probability* (F)	3	ECEN 3---	Advanced Analog Core	3
ECEN 3---	Advanced Analog Core	3		Track Course/Tech Electives**	6
ECEN 3---	Advanced Analog Core	3		Upper-division writing	3
	Humanities & Social Sciences	3		Free Elective	3
	TOTAL CREDIT HOURS	15		TOTAL CREDIT HOURS	18

Senior Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
ECEN 4610	Capstone Lab: Part 1 (F)	3	ECEN 4260	Capstone Lab: Part 2 (S)	3
	Track Course/Technical Electives**	8		Track Course/Tech Electives**	9
	Humanities & Social Sciences	3		Humanities/Social Sciences	3
	Free Elective	3			
	TOTAL CREDIT HOURS	17		TOTAL CREDIT HOURS	15

Electrical and Computer Engineering Curriculum

Key: F = course offered only in the fall semester; S = course offered only in the spring semester; SM = course offered in summer; D = undergraduate and graduate course

Math
(19 hours, minimum grade of C- required)

Course Name	Hours	Notes
APPM 1350 Calculus 1 for Engineers	4	
APPM 1360 Calculus 2 for Engineers	4	
APPM 2350 Calculus 3 for Engineers	4	
APPM 2360 Diff Equations w/ Linear Algebra	4	
ECEN 3810 Probability (May substitute APPM 3570 or MATH 4510 only)	3	F

Physics (9 hours)

PHYS 1110 General Physics 1	4	
PHYS 1120 General Physics 2	4	
PHYS 1140 Experimental Physics 1	1	

Freshman Elective (3-5 hours) choose one:

ECEN 1400 Intro to Digital/Analog Elect.	3	
GEEN 1400 Freshman Projects (or Freshman Projects from other Engr. Dept.)	3	
CHEM 1131 General Chemistry 2 (AP/transfer)	5	

Freshman Seminar (1 hour) choose one:

ECEN 1100 Freshman Seminar	1	
GEEN 1500 Introduction to Engineering (or Freshman Seminar from other Engr. Dept.)	1	

General Science Elective
(3-5 hours, choose one)

PHYS 2130 General Physics 3	3	
MCEN 3012 Thermodynamics	3	
IPHY 3410 Intro to Human Anatomy	3	
EBIO 1210 General Biology 1 (lab optional)	3	
MCDB 1150 Intro to Molecular Biology	3	
CHEN 1211General Chemistry for Engineers (with CHEN 1221 lab)	5	

Computer Programming (4 hours)

Course Name	Hours	Notes
ECEN 1310 C Programming for EE/ECE*	4	

**May substitute CSCI 1300 only for transfers*

Sophomore Electives (3 hours) choose one:

ECEN 2410 Renewable Energy (also as ECEN 2060)	3	F
ECEN 2420 Electronics for Wireless Communication	3	S
ECEN 2440 Application of Embedded Systems (also as ECEN 2020)	3	F

Electrical Engineering Core (18 hours)

ECEN 2250 Intro to Circuits & Electronics	3	
ECEN 2260 Circuits as Systems	3	
ECEN 2270 Electronics Design Lab	3	
ECEN 2350 Digital Logic	3	
ECEN 3350 Programming of Digital Systems	3	
ECEN 3360 Digital Design Lab	3	

Computer Engineering Core (10 hours)

ECEN 2703 Discrete Math for Computer Engineers	3	F
CSCI 2270 Data Structures	4	
ECEN 4593 Computer Organization	3	S

Advanced Analog Core (6 hours, choose two)

ECEN 3250 Microelectronics	3	
ECEN 3300 Linear Systems	3	
ECEN 3400 Fields	3	

Humanities/Social Sciences (21 hours)

1000/2000 A&S Core Lower Division	12	
3000/4000 A&S Core Upper Division	6	
WRTG Approved upper-division writing	3	

Track Courses (6 hours)

Must fulfill requirements for one "track" (see page 24)

Course Name	Hours	Notes
ECEN 4011 Design of Implantable Devices (even yrs)	3	S, D
ECEN 4021 Engineering Apps in Medicine (odd yrs)	3	S, D
ECEN 4242 Communication Theory	3	F
ECEN 4652 Communication Lab	3	S, D
ECEN 4532 Digital Signal Processing Lab	3	S, D
ECEN 4632 Intro to Digital Filtering	3	F
ECEN 3410 EM Waves & Transmissions	3	S
ECEN 4634 Microwave/RF Lab	3	F, D
ECEN 3320 Semiconductor Devices	3	S
ECEN 4555 Prin of Energy Systems/Devices	3	F, D
ECEN 4015 Photovoltaic Devices (fall 2015)	3	F
ECEN 4606 Undergrad Optics Lab	3 *F*	
ECEN 4616 Optoelectronic System Design	3	varies
ECEN 4106 Photonics	3	varies
ECEN 4116 Intro to Optical Communication	3	varies
ECEN 3170 Electromagnetic Energy Conversion 1	3	F
ECEN 4167 Electromagnetic Energy Conversion 2	3	S
ECEN 4797 Intro to Power Electronics	3	F, D
ECEN 4517 Renewable Power Electronics Lab	3	S, D
ECEN 4138 Control Systems Analysis	3	F, D
ECEN 4638 Controls Lab	3	S

Technical Electives (variable, typically 6-12 hours)

Use other 3000/4000 technical courses in ECEN, other engineering departments, APPM, MATH, PHYS to complete 128 hour requirement.

Non-track ECEN Technical Electives for EE

ECEN 4653 Real-Time Digital Media Systems	3	*S*
ECEN 4224 High-Speed Digital Design	3	*S, D*
ECEN 4324 Fund of Microsystem Packaging	3	*F, D*
ECEN 4--- Selected Special Topics	3	

May also use 3000/4000 level technical courses in other engineering departments, APPM, MATH and PHYS
In addition, up to 6 hrs EMEN/Business/ECON may be applied. See rules on page XX. Check with Advisor for applicability.

Software Electives (3-4 hours) choose one:

ECEN 4553 Compiler Construction (even years)	3	*F/D*
CSCI 3202 Intro to Artificial Intelligence	3	*F*
CSCI 3287 Database & Information Systems	3	*F*
CSCI 3308 Software Engr Methods & Tools	3	*F*
CSCI 3753 Operating Systems	4	*S*
CSCI 4113 Unix Systems Administration	3	*S*
CSCI 4229 Computer Graphics	3	*F, SM*
CSCI 4273 Network Systems	3	
CSCI 4423 Chaotic Dynamics	3	
CSCI 4838 User Interface Design	3	*S*

Capstone Design Lab (6 hours, minimum grade of C- required)

ECEN 4610 Capstone Laboratory, Part 1	3	*F*
ECEN 4620 Capstone Laboratory, Part 2	3	*S*

Free Electives (6 hours maximum)

Student choice of courses

Sample Schedule for Electrical & Computer Engineering

Freshman Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
APPM 1350	Calculus 1	4	APPM 1360	Calculus 2	4
PHYS 1110	Physics 1	4	PHYS 1120	Physics 2	4
ECEN 1100	Freshman Seminar (F)	1	PHYS 1140	Experimental Physics	1
ECEN 1400	Freshman Elective*	3	ECEN 1310	C Programming for EE/ECE*	4
	Humanities/Social Sciences	3		Humanities/Social Sciences	3
	TOTAL CREDIT HOURS	15		TOTAL CREDIT HOURS	16

Sophomore Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
APPM 2360	Diff. Eq. with Linear Algebra	4	APPM 2350	Calculus 3	4
ECEN 24--	Sophomore Elective 1	3	ECEN 2350	Digital Logic	3
ECEN 2250	Intro to Circuits & Electronics	3	ECEN 2260	Circuits as Systems	3
ECEN 2703	Discrete Mathematics (F)	3	ECEN 2270	Electronics Design Lab	3
	Humanities & Social Sciences	3		General Science Elective**	3
	TOTAL CREDIT HOURS	16		TOTAL CREDIT HOURS	16

Junior Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
ECEN 3350	Programming of Digital Systems	3	ECEN 3360	Digital Design Lab	3
ECEN 3810	Probability* (F)	3	ECEN 3---	Advanced Analog Core	3
ECEN 3---	Advanced Analog Core	3		Software Elective	3
CSCI 2270	Data Structures	3		Track Course/Tech Electives**	6
	Humanities & Social Sciences	3		Upper-division writing	3
	TOTAL CREDIT HOURS	15		TOTAL CREDIT HOURS	18

Senior Year

Fall			Spring		
Course	**Title**	**Hours**	**Course**	**Title**	**Hours**
ECEN 4610	Capstone Lab: Part 1 (F)	3	ECEN 4260	Capstone Lab: Part 2 (S)	3
	Track Course/Tech Electives**	7		Track Course/Tech Electives**	3
	Humanities & Social Sciences	3	ECEN 4593	Computer Organization	3
	Free Elective	3		Humanities/Social Sciences	3
				Free Elective	3
	TOTAL CREDIT HOURS	16		TOTAL CREDIT HOURS	15

Prerequisites, Co-requisites and Terms Offered

Course	Title	Prerequisites and Co-requisites	Term
General Courses		***Only final prerequisites are listed.***	
1310	C Programming for ECE (was 1030)	none	
1400	Intro to Digital & Analog Electronics	APPM 1350 (co-req)	
2250	Intro to Circuits & Electronics	APPM 2360 (co-req), PHYS 1120, ECEN 1310 (recommended)	
2260	Circuits as Systems	ECEN 2250	
2270	Electronics Design Lab	ECEN 1310, ECEN 2260 (co-req)	
2350	Digital Logic	ECEN 1310 or CSCI 1300	
2703	Discrete Mathematics	ECEN 1310 or CSCI 1300, APPM 1360	Fall
3250	Microelectronics	ECEN 2260	
3300	Linear Systems	ECEN 2260	
3350	Programming Digital Systems	ECEN 2350	
3360	Digital Design Lab	ECEN 3350	
3400	Electromagnetic Fields	APPM 2350, APPM 2360, ECEN 2250	
3810	Introduction to Probability	APPM 2350	Fall
4610	Capstone Laboratory 1	ECEN 3360, final Advanced Analog concurrent	Fall
4620	Capstone Laboratory 2 (minimum C- required)	ECEN 4610 & 2 (ECE) or 3 (EE) Advanced Analog Electives	Spring
Biomedical and Engineering			
4/5011	Design of Implantable Devices	ECEN 2260	Spring even yrs
4/5021	Engineering Applications in Medicine	ECEN 2260	Spring odd yrs
Communication and Signal Processing			
4242	Communication Theory	ECEN 3300, 3810	Fall
4/5532	DSP Laboratory	ECEN 3300, 4632	Spring
4632	Introduction to Digital Filtering	ECEN 3300	Fall
4652	Communication Laboratory	ECEN 3300, 4242	Spring
Computer Engineering			
2440	Application of Embedded Systems (also 2020)	ECEN 1310 or CSCI 1300	
4553	Introduction to Compiler Construction	ECEN 2350, 2703	Fall
4593	Computer Organization	ECEN 3360	
4/5613	Embedded Systems Design	ECEN 3360 (3250, 4593 recommended)	
4/5623	Real-Time Embedded Systems	ECEN 3360 (4613 recommended)	Fall
4/5643	SW Engineering of Concurrent Systems	ECEN 4583 or 5543	
4/5653	Real-Time Digital Media	ECEN 1310, CSCI 3753 (see catalog for prereqs)	Spring
4/5743	SW Engineering of Distributed Systems	ECEN 4583 or 5543, (4/5643 recommended)	
Dynamics and Controls			
4138	Control Systems Analysis	ECEN 3300	Fall
4638	Control Systems Laboratory	ECEN 4138	Spring
Electromagnetics, RF, and Microwaves			
2420	Electronics for Wireless Communication	PHYS 1120, APPM 1360, ECEN 2250 pre/coreq	Spring
3410	Electromagnetic Waves & Transmission	ECEN 3400	Spring
4/5224	High Speed Digital Design	ECEN 3400	Spring
4/5324	Microsystem Packaging	ECEN 3400, (3410 recommended)	Fall

Course	Title	Prerequisites and Co-requisites	Term
General Courses		***Only final prerequisites are listed.***	
4/5634	Microwave & RF Lab	ECEN 3410	Fall
Nanostructures and Devices			
3320	Semiconductor Devices	ECEN 3250	Fall
4xx5	Photovoltaic Devices	ECEN 3320	Fall
4/5555	Principles of Electrical Energy Systems	ECEN 3810, PHYS 2130 or 2170 (co-req)	Fall
Optics and Photonics			
4116	Intro to Optical Communication	ECEN 3400	Fall
4606	Optics Laboratory	ECEN 3400 or PHYS 4510	Fall
4616	Optoelectronic System Design	ECEN 3400	Spring
Power Electronics and Renewable Energy Systems			
2410	Renewable Sources/Efficient Energy Syst	PHYS 1120 or ECEN 2250 (co-req)	Fall
3170	Electromagnetic Energy Conversion 1	PHYS 1120, ECEN 3250 (co-req)	Fall
4167	Electromagnetic Energy Conversion 2	ECEN 3170	Spring
4/5517	Renewable Power Electronics Lab	ECEN 4797	Spring
4/5797	Introduction to Power Electronics	ECEN 3250	Fall
Minimum grade required for all prerequisite courses is C-.			

Miscellaneous Curriculum Notes

It is necessary that you take APPM 2360 (Differential Equations with Linear Algebra). Material covered in APPM 2360 will help you with ECEN 2250 and must be taken as a co-requisite if not taken prior to 2250. This will likely mean taking APPM 2360 before APPM 2350 (Calculus 3).

Because the curriculum is in transition, the numbers associated with the core courses may change. The course titles, however, should remain the same. Always check the schedule for the upcoming semester on the website.

The minimum grade allowed for Capstone Lab 1 ECEN 4610 and Capstone Lab 2 ECEN 4620 is C-. Both classes must be taken in consecutive semesters. If the grade in 4610 is below minimum the student will not be allowed to enroll in 4620. ECEN 4610 will have to be retaken the following fall in order to continue to 4620. If 4610 is successfully completed but the grade for ECEN 4620 is below minimum, both courses will need to be retaken the following year.

Other Important Publications and Links

- University of Colorado Catalog: Degree requirements, academic standards, administrative regulations, university policies and procedures - www.colorado.edu/catalog
- College Information: College of Engineering & Applied Science requirements, rules and regulations - www.colorado.edu/engineering
- Registrar’s Office: Deadlines, instructions for registration and drop/add, transcript requests, calendars – www.colorado.edu/registrar

Theory and Lab (Track) Course Schedule

Biomedical Engineering

- ECEN 4011 Design of Implantable Medical Devices (spring even yrs)
    - Prerequisite: ECEN 2260 Circuits as Systems
- ECEN 4021 Engineering Applications in Medicine (spring odd yrs)
    - Prerequisite: ECEN 2260 Circuits as Systems

Communication

- ECEN 4242 Communication Theory (fall)
    - Prerequisites: ECEN 3300 Linear Systems and ECEN 3810 Probability or approved substitute
- ECEN 4652 Communication Lab (spring)
    - Prerequisite: ECEN 4242 Communication Theory

Digital Signal Processing

- ECEN 4632 Intro to Digital Filtering (fall)
    - Prerequisite: ECEN 3300 Linear Systems
- ECEN 4532 Digital Signal Processing (DSP) Lab (spring)
    - Prerequisite: ECEN 4632 Intro to Digital Filtering

Dynamics & Controls

- ECEN 4138 Control Systems Analysis
    - Prerequisite: ECEN 3300 Linear Systems
- ECEN 4638 Controls Lab
    - Prerequisite: ECEN 4138 Control Systems Analysis

Electromagnetics, RF & Microwaves

- ECEN 3410 Electromagnetic Waves & Transmission (spring)
    - Prerequisite: ECEN 3400 Electromagnetic Fields & Waves
- ECEN 4634 Microwave/RF Lab (fall)
    - Prerequisite: ECEN 3410 EM Waves & Transmission

Nanostructure Materials & Devices

- ECEN 4555 Principles of Energy Systems & Devices (fall)
    - Prerequisite: Probability and PHYS 2130 or 2170
- ECEN 3320 Semiconductor Devices (spring)
    - Prerequisite: ECEN 3250 Microelectronics
- ECEN 4005 Photovoltaic Devices
    - Prerequisite: ECEN 3250 Microelectronics

Optics & Photonics

- ECEN 4616 Optoelectronic System Design (fall)
    - Prerequisite: ECEN 3400 Electromagnetic Fields & Waves
- ECEN 4606 Undergraduate Optics Lab (fall)

- Prerequisite: ECEN 3400 Electromagnetic Fields & Waves

Power Electronics

- ECEN 4797 Intro to Power Electronics (fall)
  - Prerequisite: ECEN 3250 Microelectronics
- ECEN 4517 Renewable Power Electronics Lab (spring)
  - Prerequisite: ECEN 4797 Intro to Power Electronics

Renewable Energy

- ECEN 3170 Electromagnetic Energy Conversion 1 (fall)
  - Prerequisite: ECEN 2260 Circuits as Systems
- ECEN 4167 Electromagnetic Energy Conversion 2 (spring)
  - Prerequisite: ECEN 3170 Electromagnetic Energy Conversion 1

Humanities and Social Sciences Requirements

Students must complete 18 credit hours in approved courses in the Humanities and Social Sciences and 3 credit hours in an approved upper division writing course. These courses are all included in the 21 hours required for Humanities & Social Sciences in the online degree audit in mycuinfo.

Writing

3 credit hours in one of the following courses: HUEN 1010 (for first year freshmen only), WRTG 3030, WRTG 3035, PHYS 3035, HUEN 3100. Upper-division transfer courses may be approved by petition.

Humanities and Social Sciences

18 credit hours of approved courses, of which 6 must be at the 3000 level or higher. Courses approved for the 18 credit-hour H&SS requirement:

- Any course included in the following acceptable categories of courses in the Arts &Sciences Core found from the A&S Core Curriculum web page and through the Search for Courses in mycuinfo registration tab:
  - Contemporary Societies
  - Culture & Gender Diversity
  - Foreign Language
  - Historical Context
  - Ideals and Values
  - Literature and the Arts
  - United States Context

See www.colorado.edu/engineering/academics/policies/hss for assistance in selecting approved courses. Any exceptions must be approved by petition to the department and college. Also see “Quick Humanities Search Instructions” found at http://ecee.colorado.edu/academics/ugrad/overview.html.

Approval is granted for any group of four courses that would count toward a minor field in any of the following departments in the College of Arts and Sciences: Economics, Ethnic Studies, History, Linguistics, Philosophy, Political Science, Religious Studies, or Women’s Studies. (Note: These courses are approved for H&SS credit only if taken as a group of four courses that would count toward a minor field.) For further information on minor fields, see www.colorado.edu/advising/programs-requirements.

Herbst Program of Humanities

All courses taught through the Herbst Program of Humanities for Engineers and have "HUEN" as their prefix are approved. The centerpiece of the Herbst Program is a two-semester seminar sequence open to juniors and seniors. These seminars are limited to 12 students and are devoted to roundtable discussions of original texts, primarily in literature and philosophy, but with secondary attention to art, music and architecture. These seminars also help our students improve their writing skills, gain confidence and skill in civil discourse on controversial issues, see more clearly the inadequacy of dogmatic responses to complex questions, and develop intellectual rigor on non-technical issues. Students must apply to participate in the Junior Seminars, which also satisfy the University's required writing course.

The Herbst Program also offers courses at other levels. HUEN 1010 is similar to HUEN 3100 in being a text-based seminar, but it is designed for freshmen. In HUEN 1100, History of Science & Technology, original source material and textbook readings provide insight into science and technology in changing historical, social, and political contexts. For freshmen and sophomores, Herbst offers Tradition and Identity, HUEN 2010, which explores the following questions: Why am I who I am, and why do I desire my future to look a certain way? What ways, both positively and negatively, does tradition determine/influence the possibilities of my individuality?

For a full list of courses and other information, visit www.colorado.edu/engineering/herbst.

Graduation Checklist

- ☐ Successfully complete a minimum of 128 semester credit hours according to the curriculum in effect at the time the student was officially admitted to the EEEN or ECEN degree program. The last 45 credit hours must be earned as a degree student in classes at the Boulder campus after admission to the College of Engineering and Applied Science unless exempted by prior petition.
- ☐ Achieve a cumulative grade point average of 2.25 or better in all courses taken at the University of Colorado (all campuses) as well as a grade point average of 2.25 or better in all courses taken from, or cross listed in, the Department of Electrical, Computer, and Energy Engineering.
- ☐ Satisfy any outstanding MAPS deficiencies. These deficiencies should have been resolved in the first year or two of enrollment in the College, but students cannot graduate without having met the basic requirements in effect at the time of their admission.
- ☐ Meet with the Undergraduate Advisor two semesters prior to intended graduation for a comprehensive review and approval of remaining courses needed to satisfy graduation requirements.
- ☐ Complete the Application for Graduation online using MyCuInfo. Deadlines for completion of the application process will be announced by the Registrar's Office, the Engineering Dean and the Undergraduate Advisor.
- ☐ If you are completing a minor, a Minor Completion form must be submitted to the Undergraduate Staff Advisor's Office prior to graduation.

It is the responsibility of each student to be certain that all degree requirements have been met and to keep the Department informed of any change in graduation plans.

ECEN Track Courses

Choosing Theory and Elective Track Courses

The body of knowledge found under Electrical, Computer, and Energy Engineering is far too large to be obtained in only four years of college. Because of the continual appearance of new technologies, new tools, and new opportunities, this body of knowledge gets ever larger. This situation is not a matter of concern, but it is merely the inevitable consequence of healthy growth in the profession.

As a student of the profession, you need to have a combination of broad and narrow studies. All Electrical Engineers share a special vocabulary and a core knowledge of things electrical. Because the range of application is so large, it is necessary for you to sample some areas of specialization. This section has been prepared to help you select upper division courses in areas of interest (tracks) in which you might eventually specialize. The areas chosen reflect the individual research interests and expertise of our faculty. Faculty members in each area have written the one-page descriptions.

Each track lists prerequisite courses (normally from the ECEE core) and the courses that must be taken to complete the track. As part of the curriculum requirements, EE majors must complete at least two tracks, while ECE majors must complete at least one track.

Should you develop an interest for further study, or would like to be involved in some independent work, you should consult one or more of the faculty listed. Faculty contact information is available on page 48 and also on the ECEE web site.

Finally, be sure to consult the current University Course Catalog or the Course Schedule (found on a link from the front page of the department's site) for course descriptions. Several of the areas have listed follow-on graduate courses for those interested in further study.

Communications

- Core prerequisite: Linear Systems, ECEN 3300
- Courses: ECEN 4242 Communication Theory and ECEN 4652 Communication Lab
- Faculty advisors: E. Liu, P. Mathys, M. Varanasi

One of the most fascinating and important topics in electrical communications is the wireless transmission and reception of analog and digital signals. Early examples, most of which are still in use today, include wireless communication using Morse signals and AM (amplitude modulation) and FM (frequency modulation) radio broadcasts. Modern examples of wireless systems are satellite radio and TV, wireless LANs (local area networks), and cellular telephones.

All practical communication systems are affected by noise that is picked up during transmission, either by the communication channel itself or by the front-end of the receiver, and the signal-to-noise ratio (SNR) of the received signal is a crucial measure for the quality of a communication system. For analog systems quality is synonymous with high fidelity reproduction of the transmitted signal. For digital systems the main quality measure is the probability of bit or symbol error. Early on, the common perception was that in order to improve quality more transmit power was needed. But it is now recognized that putting intelligence in various forms of coding into communication systems is an energy-conscious and smart alternative. Most modern communication systems use digital symbols to represent signals, independent of whether the original signal, like speech or music, is analog or, like computer data, is already digital. Source coding, like MP3, for example, and error-control coding can be applied easily to digitally represented signals. However, most physical channels require a waveform that is continuous in time and in amplitude and is restricted to a specific frequency range for efficient signal transmission. Thus, important topics for the treatment of communication systems are the study of signal processing of both analog and digital signals and the conversion between analog and digital representations.

Representative Technical Applications

- Wireless and wired transmission of analog and digital data
- Reliable reception of analog and digital data
- Information storage and retrieval
- Telephone network, cell phones, data networks
- Coding for compression, error-control, and secrecy/privacy
- Radio and TV broadcasts

Representative Societal Applications

- Voice and data communication for personal and commercial purposes
- Digital storage of multimedia including audio, images, and movies
- Wireless communication networks for remote areas
- Communications for rescue missions and disaster recovery

Digital Signal Processing

- Core prerequisite: Linear Systems, ECEN 3300
- Courses: ECEN 4632 Digital Filtering and ECEN 4532 Digital Signal Processing Laboratory
- Faculty advisors: F. Meyer

Digital Signal Processing became possible when digital computers came into existence and then became cheap enough to be considered components. Almost all the classical analog signal processing applications (like telephones, radio sets, signal generators, and oscilloscopes) can now be done digitally. DSP is done in real time or offline; it is done on one-dimensional signals like audio, and two-dimensional signals like images. Embedded processors for doing DSP are found in cell phones, audio players, digital cameras, automobile engines, braking control systems, and medical instruments. Examples of applications on large computers include seismic exploration, geophysical mapping, motion picture animation, and medical imaging. The range of application is enormous.

To study Digital Signal Processing, it is necessary to have a good grounding in discrete-time linear systems and time-frequency transformations. The essential pre-requisite for the senior DSP theory and lab courses is the Linear Systems Core course. In addition, real-time applications require experience with assembly language code development. Offline processing requires the use of high-level application languages like MATLAB. DSP is a good area for those who enjoy the design and development of algorithms, applied mathematics, and applications. Students who intend to complete degrees in both EE and Music will find the DSP lab course especially interesting.

Representative Technical Applications

- Audio generation, coding, reproduction, and enhancement
- Image Processing, enhancement, coding, and pattern recognition
- Video analysis, coding and decoding
- Wireless Communications modulation and demodulation
- The Design of dedicated DSP processors
- The use of DSP in feedback control

Representative Societal Applications

- Aids for human speech and hearing
- Aids for human vision
- Medical instruments which can see into the body and the brain

- Environmental analysis using remote sensing data

Dynamics and Controls

- Core prerequisite: Linear Systems, ECEN 3300
- Courses: ECEN 4138 Control Systems Analysis and ECEN 4638 Control Systems Laboratory
- Faculty advisors: J. Hauser, J. Marden, D. Meyer, L. Pao

Safe airplanes and vehicles, minimally invasive surgery, reliable manufacturing, computer-assisted physical rehabilitation—these all have automatic control and robotics as core technologies. Automatic control has been a key technological component since the middle of the 20th century, and with the advent of fast computers, nearly any device that moves or has dynamics has an embedded digital controller. Moreover, robotic applications have found their way into more than just automotive manufacturing. We now see robotic devices in medical, defense, and renewable power industries. Students wishing to pursue these areas will increasingly need expertise in the robotics and control areas.

To study robotics and control, students need to have taken Linear Systems Analysis (ECEN 3300) and the controls sequence early. If possible, students should take ECEN 3300 by their Spring junior term so that they can take ECEN 4138/4638 in their Fall/spring senior term. This will allow them to take a senior robotics elective. Many students find that a course in matrix methods (typically offered through the Applied Mathematics Department) is helpful in robotics and control. Other relevant courses include embedded systems and power electronics, both of which play significant roles in autonomous, robotic systems.

Representative Technical Applications

- Haptic rendering for minimally-invasive surgery
- Motion planning in uncertain environments, such as the NASA Mars rover
- Flight control of aggressive aircraft
- Reconfigurable manufacturing
- Image recognition and autonomous response
- Fast and precise control of atomic force & near field scanning optical microscopes

Representative Societal Applications

- Safe transportation
- Precise medical treatment and rehabilitation
- Efficient energy usage

Electromagnetics, RF and Microwaves

- Core prerequisite: Electromagnetic Fields, ECEN 3400
- Courses: ECEN 3410 Electromagnetic Waves and Transmission and ECEN 4634 RF & Microwave Laboratory
- Faculty advisors: D. Filipovic, A. Gasiewski, E. Kuester, M. Piket-May, Z. Popovic

The origins of electromagnetics can be traced to the earliest days of human existence. Fear and fascination with many natural phenomena including lightning lingered for thousands of years until sound physical understandings were developed. Ancient Greeks noticed that rubbing fur against amber (‘electron’ in Greek language) caused attraction between the two. The 20th century archeological findings indicate that the first battery was made in old Iraq in 3rd century BC. Many scientists and free thinking minds over the last 300 years, including Benjamin Franklin, Michael Faraday, Nikola Tesla, James Clerk Maxwell, Heinrich Hertz and others have contributed to tremendous advances in electromagnetics, and by application of electromagnetics, to electrical and electronic engineering as a whole. Try to imagine life without electrical signals, power, and modern electronic materials: radio, TV, phones, air travel, refrigeration, etc... would be virtually impossible.

The CU Electromagnetics, RF and Microwave focus area provides the necessary foundation for understanding the phenomena of electricity, magnetism and radio waves, and facilitates the engineering of a wide range of RF and microwave components, devices, sub-systems, and systems. EM theory, design, measurements and fabrication are covered on a level that enables a career in industry, government, or further education on a master or doctoral level. A background in mathematics and elementary circuits are needed. The low-frequency part of this track is the foundation for circuit theory, while the high-frequency portion merges with the optics track.

Representative Technical Applications

- Generation, transmission, propagation, and reception of radio waves
- Wireless, satellite, and cable communications, including radio and television
- Antennas for cell phones, vehicles, space exploration, navigation, and sensing
- RF and microwave transmitters and receivers
- Microwave transmission lines, amplifiers, oscillators, resonators, and filters
- Radar, concealed weapon and buried object detection; stealth design
- Remote sensing of Earth and planetary surfaces, oceans, atmospheres, and cryospheres
- RF tagging, telemetry, therapeutic and industrial heating
- Acoustic sensing and communications; seismic sensing

Representative Societal Applications

- Wireless communications and networking
- Medical instrumentation, diagnostics, treatment and therapeutics
- Alternative energy resources – wireless power harvesting
- Environment sensing, monitoring, and forecasting
- Border control, defense, homeland security

Possible follow-on courses

- ECEN 5114 Waveguides and Transmission Lines
- ECEN 5134 Electromagnetic Radiation and Antennas
- ECEN 5104 Computer-Aided Microwave Circuit Design
- ECEN 5254 Radar and Remote Sensing

Nanostructure Materials & Devices

- Prerequisites: Microelectronics, ECEN 3250 (Modern Physics PHYS 2130 recommended)
- Courses (choose two to complete the track): ECEN 3320 Semiconductor Devices, ECEN 4555 Principles of Energy Systems & Devices (requires PHYS 2130 but not ECEN 3250) and ECEN 4005 Photovoltaic Devices
- Faculty advisors: J. Gopinath, G. Moddel, W. Park, S. Shaheen, B. Van Zeghbroeck

Materials and device electronics dominated technological advances in the 20th century, and are advancing at an accelerated rate in the 21st century. Early electronics used the vacuum tube, but about 50 years ago this gave way to solid state electronics based on semiconductors. This enabled the growth of the microelectronics industry, integrated circuits, superconductor devices, and more recently practical use of solar cells. Virtually all audio, video, communications, computing and more recently aerospace and automotive technologies are based on microelectronic devices. During the last few years, nanostructured materials and nano-scale (below 1 micron) devices have allowed the fabrication of devices that were not even dreamed of earlier.

Nanostructures is based upon a solid understanding of modern physics as well as a “feel” for physical structures. In addition to the physics courses required for the EE degree, it would be useful to take PHYS 2130 Modern Physics as early as possible. The stepping-off point to junior and senior-level nanostructures courses is ECEN 3250 Microelectronics. ECEN 3320 Semiconductor Devices, ECEN 4555 Principles of Energy Systems & Devices (ECEN 3250 not required), and ECEN 4005 Photovoltaic Devices can be taken in any order. Semiconductor Devices and Photovoltaic Devices use underlying physics to develop an understanding of electronics and solar cell technology. Principles of Energy Systems & Devices develops thermodynamics concepts to explore energy technologies.

Representative Technical Applications

- Lower-power portable devices
- Lasers and solid-state lighting devices
- Flat-panel displays
- Solar cells
- Energy conversion devices and systems
- Higher-density computers and memories
- Digital cameras and photodetectors

Representative Societal Applications

- Alternative energy devices
- Internet, communications and entertainment
- Nano-scale electronic devices for medical implants
- Medical imaging, cancer detection and therapeutics

Neural and Biomedical Engineering

- Core prerequisite: Circuits as Systems, ECEN 2260
- Courses (choose two to complete the track): ECEN 4011 Design of Implantable Medical Devices, ECEN 4021 Engineering Applications in Medicine and ECEN 4053 Assistive Technologies for People with Disabilities
- Faculty advisors: M. Lightner, R. Mihran

The roots of electrical engineering and neuroscience both go back to the late 18th century when scientific debates as to the fundamental nature of electricity and its role in the neural control of muscle activity were raging. For example, the Italian physiologist and anatomist Luigi Galvani built a sensitive device (subsequently known as a Galvanometer) used it to, he claimed, detect electrical activity in active frog muscles. His fellow Italian, physicist Alessandro Volta, however, disputed this and suggested instead that the electrical potentials (subsequently known as Voltages) that Galvani registered were due to the interface of metal wires with the muscle tissue. To prove his point Volta showed that you could generate voltages simply by interfacing metal plates with salt solutions—and in so doing he invented the battery! History would prove that both Galvani and Volta were correct in their own context and ever since progress in electrical and neural sciences has been intrinsically linked.

Today, this strong linkage between ECE and Neural Sciences has re-emerged as a field called Neural Engineering or Neurotechnology, and it is well represented in the course offerings open to junior and senior (as well as first-year graduate) EE/ECE students.

The NE track does not require any previous coursework in biology. The courses listed above are designed to be comprehensible to engineering students with no prior biological background.

Representative Technical Applications

- Measurements of biomedically important signals

- Algorithms for biomedical signal processing and display
- Technologies for imaging body anatomy (MRI, CAT, etc.) and imaging neuroelectric activity patterns (FMRI, etc.)
- Studying the molecular and cellular basis of bioelectrical phenomena
- Applying control theory and signal flow concepts to physiological systems
- Quantifying and understanding the biological effects of electromagnetic fields
- Modeling the genesis and propagation of neuromagnetic fields
- Improving neurosurgical techniques such as Deep Brain Stimulation

Representative Societal Applications
- Improved diagnoses and treatment for cardiac, vascular, and pulmonary diseases.
- Improved diagnoses and treatment for neural diseases.
- Development of assistive devices for cognitive disabilities
- Development of brain controlled prostheses for disabled patients.
- Better understanding of health risks (or lack thereof) posed by EMF devices.
- Refinement of "artificial intelligence" to be more like actual cognitive function.

Optics and Photonics

- Core prerequisite: ECEN 3400 Electromagnetic Fields & Waves and ECEN 3300 Linear Systems
- Courses: ECEN 4606 Undergraduate Optics Lab and ECEN 4616 Optoelectronic System Design
- Faculty advisors: J. Gopinath, R. McLeod, A. Mickelson, R. Piestun, M. Popovic, K. Wagner

From LCD displays and CMOS cameras, fiber optics and telecommunications, to medical and astronomical imaging, optics and photonics are critical to many modern technologies. Based on the science of light, optics and photonics are at the confluence of electrical and optical engineering with applied physics. Iconic developments that are prevalent in daily life such as the laser, holography, liquid crystal displays, charge coupled device (CCD) detectors, and fiber optics are being extended by CU faculty into future applications such as silicon photonics, computational imaging, nano-lithography, biophotonics, femtosecond lasers, and quantum and optical computing.

The study of Optics and Photonics requires a background in electromagnetic fields and waves and the interaction of light with matter, as well as the system viewpoint of linear systems and communication theory. Thus, both fields and linear systems are required prerequisites of the Photonics Theory/Lab senior electives.. Theory courses in either Photonics, Optics, Optical Electronics, or Optical Systems Design can be followed with more advanced courses such as Physical or Fourier optics or others offered in the department of ECEE.

Representative Technical Applications
- Laser diodes, solid state lasers, tunable lasers, ultrafast lasers, and other novel light sources
- Holography for display and storage, interferometric metrology
- Fiber optic components, lasers, detectors, amplifiers, modulators
- Microscopes, Telescopes, Spectrometers, Polarimeters, Interferometers
- Quantum optics, quantum encryption, quantum information processing
- Nonlinear optics based information processing, frequency conversion

Representative Societal Applications
- Optical data storage (CDs, DVDs, holographic storage)
- Fiber optic communication (internet backbone, fiber to the home)
- Imaging (digital cameras for consumer, microscopy, medical, defense, astronomy applications)
- Displays (for computers, portable devices, video and art, including 3-D displays)
- Electronic-photonic circuits (next generation ICs and planar lightwave integrated circuits)
- Lasers sources (precision metrology, spectroscopy, time and frequency standards)

- Energy conversion (semiconductor and organic solar cells)

Alternate Theory Course
- ECEN 4645 Optical Electronics

Advanced follow-on courses
- ECEN 5696 Fourier Optics and Imaging
- ECEN 5156 Physical Optics
- ECEN 5166 Guided Wave Optics

Power Electronics

- Core prerequisite: ECEN 3250 Microelectronics
- Courses: ECEN 4797 Introduction to Power Electronics and ECEN 4517 Power Electronics Laboratory
- Faculty advisors: K. Afridi, R. Erickson, D. Maksimovic

Although vast majority of electronic signal processing and computing is now performed digitally, signal and power generation and delivery remain fundamentally analog. Interfaces between sensors such as microphones, temperature, motion or optical sensors and digital computers involve analog signal conditioning and analog-to-digital conversion. Similarly, digital computer outputs, such as audio or communication signals must be ultimately converted to real-world analog signals via digital-to-analog converters. All electronic systems require efficient, tightly regulated power supplies. Advances in power electronics have enabled improved operating life of battery powered electronics, significant energy savings and reductions in size and cost in all electronic systems, as well as more effective utilization of renewable energy sources such as wind or solar. Performance of systems ranging from cell phones to audio or video players, to medical instrumentation, measurement devices, or renewable energy systems is often determined by the noise, bandwidth or efficiency of analog and power microelectronics.

Basic understanding of transistors and other semiconductor devices, as well as circuit analysis techniques in time and frequency domains, are necessary to learn about circuit design techniques in microelectronics. ECEN 2250, ECEN 2260 and ECEN 3250 are therefore essential prerequisites for the senior power electronics and analog integrated circuit design courses. In the Introduction to Power Electronics and the Power Electronics Laboratory, we address analysis, modeling and design of switched-mode power conversion circuits capable of supplying arbitrary tightly regulated voltages and currents at very high efficiencies. The lab culminates with a project where students design, build and test power electronics for a complete solar power system. Analog Integrated Circuits Design addresses transistor-level circuit design of current and voltage references, amplifiers, comparators, analog-to-digital and digital-to-analog converters with numerous applications in audio, video, radio-frequency and sensor interfaces. Microelectronics is a good area for those who enjoy hands-on circuit design, experimentation, and applications.

Representative Technical Applications
- Efficient electrical power processing and power management
- Signal conditioning, analog-to-digital and digital-to-analog conversion
- Audio, video, radio-frequency and sensor interfaces

Representative Societal Applications
- Energy efficiency and energy savings
- Effective utilization of renewable energy sources
- Computing and communication infrastructure
- Sensors and instrumentation: environmental, medical, industrial

Renewable Energy

- Core prerequisite: ECEN 2260 Circuits as Systems

- Courses: ECEN 3170 Electromagnetic Energy Conversion I (co-requisite ECEN 3250 Microelectronics) and ECEN 4167 Electromagnetic Energy Conversion II
- Faculty advisors: H. Hilgers (adjunct faculty)

Renewable energy was established as a new field about 20 years ago with the design of wind and photovoltaic power plants. Although in some areas great progress has been made, it is still insufficient to cover the electric energy needs of our nation which requires a total installed power capacity of about 800GW with a spinning reserve of about 80GW. The latter is required because the electricity consumed by residential, commercial and industrial loads must be generated at the very moment when consummation occurs. This requirement cannot be met by renewable energies alone because they are intermittent in their energy production and even meteorological forecasts cannot alleviate this problem. In addition, the change of the wind, for example, may result in the loss of 60MW per minute. This loss of generation capacity can only be covered either by conventional plants (e.g., natural gas or coal-fired plants) or by energy storage facilities, and to a lesser extent by nuclear plants which serve mostly as base load plants due to the long thermal time constants of the nuclear reactor.

Applications range from the development of new algorithms for the control of distributed systems (DG), load flow analyses for fundamental and harmonics as required by power system control centers, the development of emergency operational procedures in case of brown- or blackouts, the interaction of renewable plants with energy storage plants. From the Dutch experiences one can conclude that renewable energy of 30% of the entire required power, that is, in our nation's case 240GW, poses tremendous control problems. Needless to say, the range of application is enormous.

To study renewable energy systems, it is necessary to have a good grounding in basic laws and theorems of electrical engineering. The prerequisite for the sophomore, senior, and cross-listed graduate courses is Circuits and Electronics 1 and 3. In addition, real-time applications require some experience in computer languages such as Quick Basic, C++, D/D, D/A and A/D converters, and other soft- and hardware. Off-line processing requires the use of high-level application languages like MATLAB, MATHEMATICA and SPICE. The renewable energy field is a good area for those who want to contribute to solving the problems of society and who enjoy the design and development of power system and power electronic components, applied mathematics, and applications.

Representative Technical Applications

- Renewable energy sources such as wind- photovoltaic and co-generation
- Large-scale energy storage to mitigate intermittent nature of renewable sources: design of pumped-storage hydro plants, compressed air storage plants, emergency and standby power supplies, and uninterruptible power supplies for data processing equipment
- Design of large-scale machines, rectifiers and inverters
- AC and DC transmission of electrical energy, voltage- and frequency control of systems with distributed generation
- Energy conservation
- Replacement of internal combustion engine (IC) by electric drives based on either fuel cells or batteries/supercapacitors

Representative Societal Applications

- Reduction of particulates, sulfur and carbon dioxide emissions
- Providing fuel (electricity from renewable sources) for public and individual transportation

Program Enrichment Options

Concurrent BS/MS Program

Students with strong academic records who plan to continue in the Graduate School for a Masters in the same discipline usually find it advantageous to apply for admission to the concurrent BS/MS degree program.

Purpose of the Program

The concurrent BS/MS program in Electrical, Computer, and Energy Engineering enables especially well-qualified students to be admitted to the MS program during the junior year of their BS program, and to work thereafter towards both the BS and MS degrees in Electrical and Computer Engineering. This program allows for early planning of the MS portion of the student's education, taking graduate courses as part of the BS degree, more flexibility in the order in which courses are taken, and more efficient use of what would otherwise be a final semester with a light credit hour load. Due to the tighter coordination of courses within the ECEE Department than is possible for students who come to UCB from other institutions to pursue the MS degree, up to six (6) credit hours may be counted toward both the BS and MS degree programs.

Admission to the Program

Application for admission to the Concurrent BS/MS program in the ECEE Department may be made at any time during or after the student enters his or her junior year. Minimum requirements for admission to the concurrent program are: (i) completion of the eight core EE courses, (II) a minimum overall GPA of 3.25, (iii) a minimum GPA of 3.25 in ECEE Department courses, and (iv) at least three (3) letters of recommendation must be provided by the applicant (at least two (2) must be from ECEE faculty at UCB). Transfer students in place of requirement (i) above, must have taken at least two (2) of the core ECEE courses at the Boulder campus and have completed coursework at another institution (or other institutions) which is approved for the transfer credit equivalent to all ECEE core courses not taken on the Boulder campus, and must have completed at least 15 credit hours of total courses at UCB in order to qualify for admission.

Staying in the Program

The student must maintain a GPA of at least 3.0 over all undergraduate courses taken, and a GPA of at least 3.0 in all graduate courses taken in order to remain in good standing in the program.

Regulations

Until a student in this program reaches a total of 128 credit hours of courses applicable to the BS or MS degree in Electrical and Computer Engineering taken and passed (each with a grade of D or better), he/she will be governed by the rules and regulations applicable to any undergraduate student in the ECEE Department, unless specified otherwise in the regulations described herein. After a student has accumulated a total of 128 applicable credit hours, he/she will be governed by the rules and regulations applicable to any graduate student in the ECEE Department, unless specified otherwise in the regulations described herein. It is the intention of the department that, as far as possible, a student in this program is treated on the same basis as any other student in the department at a comparable stage of their academic career.

Overlapping Credit

With the recommendation of the student's academic advisor and the approval of the ECEE Graduate Coordinator, as many as six (6) credit hours of ECEE Department courses at the 5000 level or above may be counted both toward the undergraduate degree requirements and the requirements for the MS degree. Therefore, the minimum number of credits for the Concurrent BS/MS degree is 152. Courses used in the BS/MS may not be used towards a PhD.

Advising

Students in the Concurrent BS/MS program must have a faculty advisor with whom they must consult to compose a degree plan, including a list of courses to be taken from the senior year through the end of the program. This plan must be filed with the Undergraduate Advisor by the end of the third week of the first semester in which the student has been admitted into the program.

Certificate Programs

Certificate programs are similar to minor programs, and upon completion will be identified on the student's transcript immediately following the semester in which the certificate was completed. It is possible that course work used to satisfy a certificate can also be used for free electives, technical electives, or humanities/social sciences electives. Check with the Undergraduate Advisor to determine how a certificate program fits in with your degree plans.

Embedded System Design

Commercially available digital systems (microprocessors, microcontrollers, memory chips, interface systems, and systems that handle image, voice, music, and other types of signals) have experienced explosive growth in the electronics industry. These devices are increasingly powerful, cheap, and flexible as design components. The certificate in embedded system design offers students the hardware and software knowledge, and the skills needed to design and implement these systems. The curriculum consists of two core courses and one elective course from an approved list. The core courses are:

- ECEN 4613 Embedded System Design
- ECEN 4623 Real-Time Embedded Systems or
- ECEN 4653 Real-Time Media Design

The list of approved electives is periodically updated and currently includes:

- ECEN 4610/20 Capstone Laboratory

Certificates in Engineering, Science & Society and Engineering Entrepreneurship

Information on these certificate programs may be found at www.colorado.edu/engineering/academics/degrees-minors-certificates/certificates.

ATLAS

The Alliance for Technology, Learning and Society (ATLAS) offers two certificates: Technology, Arts and Media (TAM) and Multidisciplinary Applied Technologies (MAT). Both require 18 credit hours. For additional information, call 303-735-6588 or visit www.colorado.edu/atlas.

College of Arts and Sciences

Arts and Sciences offers certificate programs in the following areas: Actuarial Studies, British Studies, Central and Eastern European Studies, Cognitive Sciences, Lesbian, Gay, Bisexual, and Transgender Studies, Medieval and Early Modern Studies, Neurosciences and Behavior, Peace and Conflict Studies, and Western American Studies.

Completion of specified course work in these programs entitles students to a certificate issued by the Dean of Arts & Sciences. Students interested in these programs should contact the appropriate program.

Biomedical Engineering Option (BIM)

The Biomedical Engineering (BIM) option, available to both electrical and computer engineering majors, focuses on the application of biophysical and engineering concepts to the improvement and protection of human health. Successful completion of this option is noted on a student's transcript and meets most medical school admission requirements.

Coursework in the Electrical and Computer Engineering curriculum is coupled with specialized courses linking electrical engineering to biomedical applications such as neural signals and systems, bioeffects of electromagnetic fields, therapeutic and diagnostic uses of bioelectric phenomena and medical image processing. Undergraduates may also elect independent study courses in these areas.

Students interested in the option may receive elective credit for two semesters of biology if they also complete two bioengineering courses from the ECEE offerings. One of these ECEE courses also may be used to satisfy distribution requirements. The basic BIM option includes two semesters of biology and two junior or senior bioengineering courses in the ECEE Department taken in lieu of other electives. Several of these electives are also applicable to the Boulder campus Neurosciences Program. ECEE Biomedical Engineering courses regularly offered include Special Topics in Biomedical Engineering.

For more information on pre-medical studies in ECEE, contact the Pre-Professional Advisors in the Academic Advising Center for the College of Arts & Sciences. For specific advice on fitting the BIM Option into an existing EE/ECE program, contact your undergraduate advisor.

Engineering Honors Program

The Engineering Honors Program was created as an educational experience for our very best students that not only included the classroom, but significantly transcended the classroom. The core values include:

- Excellence: Excellence is not an abstract value or virtue, but something very concrete. It is what happens when talented individuals choose to do excellent things. It requires both expecting the best from yourself and others, and being ambitious without being competitive
- Community: Belonging to a group that comes together to encourage, support, inspire and enjoy one another in the pursuit of excellence. On a very practical level, it means entering a group of advanced peers already succeeding and expanding the possibilities for you
- Opportunity: Creating an overall educational experience (special classes, research positions, internships, study abroad, service projects, mentors, leadership training) that matches your individual abilities and ambitions.

There will be a combination of college-wide and department-specific Honors experiences beginning your first semester. Learn more about EHP at www.cuhonorsengineering.com.

Other International Opportunities

Study Abroad

The Study Abroad Program housed within the Office of International Education in the Environmental Design building and has over 200 CU approved Study Abroad programs all over the world. Programs may vary in length, with summer, semester and year-long offerings. If you register for a CU program, you earn in-residence credit and are eligible for financial aid. For more information, visit studyabroad.Colorado.edu.

CU Engineering Global E 3

CU participates in the Global Engineering Education Exchange (Global E 3). CU Engineering students will be able to participate in Study Abroad and take engineering courses at over 40 universities all over the world. For more information visit www.colorado.edu/engineering/international/e3.

Engineers Without Borders

The student organization Engineers Without Borders is committed to researching sustainable development by practicing in developing countries around the world. CU Engineering students have traveled to Rwanda, Peru, Tibet and other countries to set up sustainable systems. For more information regarding this and other programs for developing communities, visit www.colorado.edu/engineering/ewb.