HELP! Guide

Fall 2007/Spring 2008

Department of Electrical and Computer Engineering
University of Colorado – Boulder
Engineering Center
Room ECEE 1B55
Campus Box 425 UCB
Boulder, CO 80309-0425
http://ece.colorado.edu

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Table of Contents

Welcome to Electrical & Computer Engineering

Welcome to the ECE Department!

We are pleased you have chosen the Electrical and Computer Engineering department. There are two baccalaureate degrees offered by the Department, B.S. in Electrical Engineering and B.S. in Electrical and Computer Engineering. Both are accredited by ABET (Accreditation Board for Engineering and Technology.

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 some cases, the rules of the Department differ from those of the College; the Department rules supersede in that case. You are responsible for knowing both sets of rules.

Because the curriculum is continually changing, in general you will be expected to follow the curriculum in effect when you entered the program as reflected in this HELP! Guide. If, for some reason, that becomes impossible, you must petition to follow a different curriculum.

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

As a freshman, you should see any of the freshman advisors or the Undergraduate Staff Advisor whenever you have questions. At the beginning of your sophomore year, you will be assigned a permanent faculty advisor for the remainder of your program.

If you have questions about curriculum requirements, department regulations, course sequences, etc., the Undergraduate Staff Advisor is the one to contact. She can perform a degree audit which will tell you the courses you have already completed and also which courses you still need to take to complete your degree requirements.

If you have technical questions about course content or the desirability of certain courses in the marketplace see a freshman advisor or your faculty advisor. Your faculty advisor may also assist you with career counseling and other similar topics.

The semester-by-semester schedule listed in this Guide is intended as a guideline; few students find that they can follow it exactly. 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.

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 of resources available on this campus. Please come see us before a problem becomes serious. If we can't help you solve your problem, we can certainly refer you to someone who can help.

Information is also available on the ECE Department web page at:
http://ece.colorado.edu
Check regularly for updated schedules, course information, faculty office hours and locations, job postings, and much more.

Electrical & Computer Engineering Advisors

Associate Chair and Head of the Undergraduate Program:

Prof. Andrew R. Pleszkun	EE 1B67	303-492-3571

Undergraduate Staff Advisor:

Ms. Valerie Matthews	EE 1B51	303-492-7671

Freshman Advisors:

Prof. James Avery	OT 240	303-492-6310
Prof. Dejan Filipovic	OT 243	303-735-6319
Prof. Thomas Mullis	OT 335	303-492-8718
Prof. Wounjhang Park	EE 248	303-735-3601

Transfer Credit Evaluator:

Prof. Ed Kuester	OT 248	303-492-5173

Academic and Career Advisors:
Your assigned faculty advisor or any ECE faculty member

Mission and Objectives for the EE/ECE Undergraduate Programs

Electrical and Computer Engineering Department Overview
The department was founded in the 1890's, 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, 3 research professors, and over 10 adjunct professors, instructors, and lecturers.

Two of our faculty are members of the National Academy of Engineering, fourteen 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 $5.2 million annually. Our research is concentrated in ten different areas, from biomedical engineering to VLSI/CAD.

Mission Statement
The Department of Electrical and Computer Engineering at the University of Colorado at Boulder is the premier undergraduate and graduate EE/ECE program in the state of Colorado and all adjoining states, as measured by reputation, national rankings, and department size. The primary mission of the ECE 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 management, business, law, medicine and even politics. While our primary focus is on engineering careers we are pleased when our graduates take, into diverse careers, their foundations in analysis, problem solving and understanding of complex systems.

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 smaller, local firms such as SpectraLogic and Level 3 Communications. Some of our graduates go on to graduate school and a few of our faculty even graduated from our program!

Electrical & Computer Engineering Disciplines

Biomedical 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 and 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 which comprise from 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 a BS Degree in Electrical Engineering (EEEN) *Department of Electrical and Computer Engineering*

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.

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.

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 he 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 a BS Degree in Electrical & Computer Engineering (ECEN) *Department of Electrical and Computer Engineering*

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.

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.

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
Electrical & Computer Engineering Curriculum
Pre-Requisites and Co-Requisites
Choosing Theory and Electives Courses
Are You Graduating?
Advising Resources

COURSES REQUIRED FOR B.S. IN *ELECTRICAL ENGINEERING* (128 HOURS)

Math (16 hours)

APPM 1350	4	Calculus 1 for Engineers
APPM 1360	4	Calculus 2 for Engineers
APPM 2350	4	Calculus 3 for Engineers
APPM 2360	4	Linear Algebra & Diff. Equations

Science (12 hours)

CHEN 1211	3	General Chemistry for Engineers
CHEM 1221	2	General Chemistry Lab
PHYS 1110	4	General Physics 1
PHYS 2130	3	General Physics 3

Freshman Elective (3-5 hours) - freshmen choose one: ☐

ECEN 1400	3	Introduction to Digital and Analog Electronics
GEEN 1400	3	Freshman Projects
CHEM 1131	5	General Chemistry 2
EBIO 1210	3	General Biology 1 *plus*
EBIO 1230	1	General Biology Lab 1
		or
MCDB 1150	3	Intro to Molecular Biology *plus*
MCDB 1151	1	Intro to Molecular Biology Lab

Introductory freshman course from any engr. Dept.

Freshman Seminar (1 hour) - freshmen choose one: ☐

ECEN 1100	1	Freshman Seminar *F*
GEEN 1500	1	Introduction to Engineering

Introductory freshman seminar from other engr. dept.

Computer Science (4 hours)

CSCI 1300	4	Computer Science 1: Programming

Electrical Engineering Core (38 hours)*

ECEN 2120	5	Computers as Components
ECEN 2250	5	Circuits/Electronics 1
ECEN 2260	5	Circuits/Electronics 2
ECEN 3100	5	Digital Logic
ECEN 3250	5	Circuits/Electronics 3
ECEN 3300	5	Linear Systems
ECEN 3400	5	Electromagnetic Fields & Waves
ECEN 3810	3	Introduction to Probability** *F*

** (may substitute MATH 4510 or APPM 3570 only)

ECE Electives (6 hours) - choose two: ☐☐

ECEN 3170	3	Energy Conversion *F*
ECEN 3320	3	Semiconductor Devices *F*
ECEN 3410	3	Electromagnetic Waves & Trans. *S*

*Students are not allowed to register for Capstone Laboratory until all Electrical Engineering Core courses are passed with a grade of C- or better.

F = fall only; S = spring only

Theory distribution courses (9 hours) - choose three from at least two different subject areas: ☐☐☐

Unused ECE Elective from list

ECEN 4106	3	Photonics *F*
ECEN 4138	3	Control System Analysis *F*
ECEN 4167	3	Energy Conversion 2 *S*
ECEN 4242	3	Communication Theory *F*
ECEN 4345	3	Intro. To Solid State *S*
ECEN 4553	3	Intro. To Compiler Construction *F*
ECEN 4583	3	Software Systems Development *S*
ECEN 4593	3	Computer Organization
ECEN 4623	3	Real-Time Embedded Systems
ECEN 4632	3	Digital Filtering *S*
ECEN 4645	3	Intro. to Optical Electronics *S*
ECEN 4703	3	Discrete Mathematics *S*
ECEN 4797	3	Introduction to Power Electronics *F*
ECEN 4811	3	Neural Sigs & Functional Brain Img. *S*
ECEN 4821	3	Neural Systems & Physiological Ctrl. *S*
ECEN 4827	3	Analog IC Design *F*
ECEN 4831	3	Brains, Minds, & Computers *F*

Capstone Design Lab (3 hours)

ECEN 4610	3	Capstone Laboratory* *(take F or S)*

Additional Laboratory Courses (4-6 hours) - choose two: ☐☐

ECEN 4375	3	Microstructures Lab *S, even years*
ECEN 4517	3	Power Electronics Lab *S*
ECEN 4532	3	Digital Signal Processing Lab *S*
ECEN 4606	3	Undergrad Optics Lab *F*
ECEN 4613	3	Embedded Systems Design
ECEN 4633	3	Hybrid Embedded Systems
ECEN 4634	2	Transmission Lab *F*
ECEN 4638	2	Controls Lab *F*
ECEN 4652	2	Communications Lab *F*

Humanities & Social Sciences (21 hours)

	12	A&S Core Lower division
	6	A&S Core Upper division
WRTG 3030	3	Writing on Science & Society or <u>equiv.</u> *(see page 12 for equiv. courses)*

Free Electives (6 hours maximum)

Student's choice of courses up to a maximum of 6 semester credit hours.

Technical Electives (variable)

3000-level or above of approved engineering, math, or physics courses or others by petition. Number of hours needed varies with hours in other categories.

TOTAL HOURS = 128

Sample Schedule for **Electrical Engineering** *Program*

Freshman Year

Fall

Course		*Title*	*Hrs.*
PHYS	1110	Physics 1	4
APPM	1350	Calculus 1	4
CSCI	1300	CS1: Programming	4
ECEN	1100	Freshman Seminar ***F***	1
		Humanities & Social Sciences	3
		Total Credit Hours	16

Spring

Course		*Title*	*Hrs.*
CHEN	1211	General Chemistry for Engineers	3
CHEM	1221	Engineering General Chemistry Lab	2
APPM	1360	Calculus 2	4
ECEN	1400	Freshman Elective (fall or spring)	3
		Humanities & Social Sciences	3
		Total Credit Hours	15

Sophomore Year

Fall

Course		*Title*	*Hrs.*
APPM	2360	Linear Algebra/Diff. Eq.	4
ECEN	2120	Computers as Components	5
ECEN	2250	Circuits/Electronics I	5
		Humanities & Social Sciences	3
		Total Credit Hours	17

Spring

Course		*Title*	*Hrs.*
APPM	2350	Calculus 3	4
ECEN	2260	Circuits/Electronics 2	5
ECEN	3100	Digital Logic	5
		Humanities & Social Sciences	3
		Total Credit Hours	17

Junior Year

Fall

Course		*Title*	*Hrs.*
ECEN	3300	Linear Systems	5
ECEN	3400	EM Fields	5
ECEN	3810	Probability ***F***	3
		Free Elective	3
		Total Credit Hours	16

Spring

Course		*Title*	*Hrs.*
PHYS	2130	Modern Physics	3
ECEN	3250	Circuits/Electronics 3	5
		ECE Elective	3
		Technical Elective	3
WRTG	????	Writing on Science & Society or equiv.	3
		Total Credit Hours	17

Senior Year

Fall

Course		*Title*	*Hrs.*
ECEN	4610	Capstone Laboratory*	3
		ECE Elective	3
		ECE Theory Elective	3
		ECE Theory Elective	3
		ECE Lab Elective	2
		Technical Elective	3
		Humanities & Social Sciences	3
		Total Credit Hours	17

Spring

Course		*Title*	*Hrs.*
ECEN	4610	Capstone Laboratory*	3
		ECE Theory Elective	3
		ECE Lab Elective	2
		Free Elective	3
		Humanities & Social Sciences	3
		Total Credit Hours	14

*Capstone Laboratory **may be taken in fall or spring.** It may be taken as soon as EE core courses are completed with a grade of C- or better. Enrollment during the Capstone semester should be restricted to a maximum of 15 credit hours.

F = fall only course; S = spring only course

COURSES REQUIRED FOR B.S. IN *ELECTRICAL & COMPUTER ENGINEERING* (128 HOURS)

Math (16 hours)

APPM 1350	4	Calculus 1 for Engineers
APPM 1360	4	Calculus 2 for Engineers
APPM 2350	4	Calculus 3 for Engineers
APPM 2360	4	Linear Algebra & Diff. Equations

Science (12 hours)

CHEN 1211	3	General Chemistry for Engineers
CHEM 1221	2	General Chemistry Lab
PHYS 1110	4	General Physics 1
PHYS 2130	3	General Physics 3

Freshman Elective (3-5 hours) - freshmen choose one: ☐

ECEN 1400	3	Intro to Digital & Analog Elect
GEEN 1400	3	Freshman Projects
CHEM 1131	5	General Chemistry 2
EBIO 1210	3	General Biology 1 *plus*
EBIO 1230	1	General Biology Lab 1
		or
MCDB 1150	3	Intro to Molecular Biology *plus*
MCDB 1151	1	Intro to Molecular Biology Lab

Introductory freshman course from other engr. dept.

Freshman Seminar (1 hour) - freshmen choose one: ☐

ECEN 1100	1	Freshman Seminar *F*
GEEN 1500	1	Introduction to Engineering

Introductory freshman seminar from any engr. dept.

Computer Science (8 hours)

CSCI 1300	4	Computer Science 1: Programming
CSCI 2270	4	CS 2: Data Structures

Electrical Engineering Core (38 hours)

ECEN 2120	5	Computers as Components
ECEN 2250	5	Circuits/Electronics 1
ECEN 2260	5	Circuits/Electronics 2
ECEN 3100	5	Digital Logic
ECEN 3250	5	Circuits/Electronics Lab 3
ECEN 3300	5	Linear Systems
ECEN 3400	5	Electromagnetic Fields & Waves
ECEN 3810	3	Introduction to Probability** *F*

** (may substitute MATH 4510 or APPM 3570 only)

Computer Engineering Core (6 hours)

ECEN 4593	3	Computer Organization
ECEN 4703	3	Discrete Mathematics *S*

*Students are not allowed to register for Capstone Laboratory until all Electrical Engineering Core courses and ECEN 4593 are passed with a grade of C- or better.

TOTAL HOURS = 128

Non-computer Theory Course (3 hours) - choose one: ☐

ECEN 3170	3	Energy Conversion *F*
ECEN 3320	3	Semiconductor Devices *F*
ECEN 3410	3	Electromagnetic Waves & Trans *F*
ECEN 4106	3	Photonics *F*
ECEN 4138	3	Control Systems Analysis *F*
ECEN 4167	3	Energy Conversion 2 *S*
ECEN 4242	3	Communication Theory *F*
ECEN 4345	3	Introduction to Solid State *S*
ECEN 4632	3	Digital Filtering *S*
ECEN 4645	3	Intro to Optical Electronics *S*
ECEN 4797	3	Introduction to Power Electronics *F*
ECEN 4811	3	Neural Sigs & Functional Brain Img. *S*
ECEN 4821	3	Neural Systems & Physiological Ctrl. S
ECEN 4827	3	Analog IC Design *F*
ECEN 4831	3	Brains, Minds & Computers *F*

Non-computer Lab Course (2-3 hours) choose one: ☐

ECEN 4375	3	Microstructures Lab *S, even years*
ECEN 4517	3	Power Lab 1 *S*
ECEN 4532	3	Digital Signal Processing Lab *S*
ECEN 4606	3	Undergrad Optics Lab *F*
ECEN 4634	2	Transmission Lab *F*
ECEN 4638	2	Controls Lab *F*
ECEN 4652	2	Communication Lab *F*

Capstone Design Lab

ECEN 4610	3	Capstone Laboratory* *(take F or S)*

Software Elective (3-4 hours) choose one: ☐

ECEN 4583	3	Software System Development
ECEN 4563	3	Compiler Code Generation
CSCI 3287	3	Database & Information Systems
CSCI 3308	3	Software Engr. Methods & Tools
CSCI 4273	3	Network Systems
CSCI 3753	4	Operating Systems
CSCI 4753	3	Computer Performance Modeling
CSCI 4576	4	High-Performance Scientific Comp 1
CSCI 4586	4	High-Performance Scientific Comp 2

Humanities & Social Sciences (21 hours)

	12	A&S Core Lower division
	6	A&S Core Upper division
WRTG 3030	3	Writing on Science & Society or <u>equiv.</u> *(see page 12 for equiv. courses)*

Free Electives (6 hours maximum)

Student's choice of courses up to a maximum of 6 semester credit hours.

Technical Electives (variable)

3000-level or above or approved Engineering, Math, or Physics courses or others by petition. Number of hours needed varies with hours in other categories.

F = fall only; S = spring only

Sample Schedule for Electrical and Computer Engineering *Program*

Freshman Year

Fall

Course		Title	Hrs.
PHYS	1110	Physics 1	4
APPM	1350	Calculus 1	4
CSCI	1300	CS1: Programming	4
ECEN	1100	Freshman Seminar ***F***	1
		Humanities & Social Sciences	3
		Total Credit Hours	16

Spring

Course		Title	Hrs.
CHEN	1211	General Chemistry for Engineers	3
CHEM	1221	General Chemistry Lab	2
APPM	1360	Calculus 2	4
ECEN	1400	Freshman Elective (fall or spring)	3
		Humanities & Social Sciences	3
		Total Credit Hours	15

Sophomore Year

Fall

Course		Title	Hrs.
APPM	2360	Linear Algebra/Diff. Eq.	4
ECEN	2120	Computers as Components	5
ECEN	2250	Circuits/Electronics I	5
		Humanities & Social Sciences	3
		Total Credit Hours	17

Spring

Course		Title	Hrs.
APPM	2350	Calculus 3	4
ECEN	2260	Circuits/Electronics 2	5
ECEN	3100	Digital Logic	5
		Humanities & Social Sciences	3
		Total Credit Hours	17

Junior Year

Fall

Course		Title	Hrs.
ECEN	3300	Linear Systems	5
ECEN	3400	EM Fields	5
ECEN	3810	Probability ***F***	3
CSCI	2270	CS2: Data Structures	4
		Total Credit Hours	17

Spring

Course		Title	Hrs.
		Software Elective	3
ECEN	3250	Circuits/Electronics 3	5
ECEN	4593	Computer Organization	3
WRTG	????	Writing on Science & Society or equiv.	3
		Total Credit Hours	14

Senior Year

Fall

Course		Title	Hrs.
ECEN	4610	Capstone Laboratory*	(3)
PHYS	2130	Modern Physics	3
		Tech Elective	3
		ECE Theory Elective	3
		ECE Lab Elective	2
		Free Elective	3
		Humanities & Social Sciences	3
		Total Credit Hours	17

Spring

Course		Title	Hrs.
ECEN	4610	Capstone Laboratory*	(3)
ECEN	4703	Discrete Mathematics ***S***	3
		Technical Elective	3
		Free Elective	3
		Humanities & Social Sciences	3
		Total Credit Hours	15

*Capstone Laboratory **may be taken in fall or spring.** It may be taken as soon as EE core courses and ECEN 4593 are completed with a grade of C- or better. Enrollment during the Capstone semester should be restricted to a maximum of 15 credit hours.

F = fall only course; S = spring only course

Prerequisites, Co-Requisites, and Cross Listings

No.	***Title***	***Prerequisites***	***Cross Listing***
1100	Freshman Seminar	None	
1400	Methods & Problems in ECE	APPM 1350 (co-req)	
2120	Computers as Components	CSCI 1300	
2250	Circuits/Electronics 1	APPM 1360, APPM 2360 (co-req)	
2260	Circuits/Electronics 2	ECEN 2250, APPM 2360	
3100	Digital Logic	CSCI 1300	
3170	Energy Conversion 1	ECEN 3250	
3250	Circuits/Electronics 3	ECEN 2260	
3300	Linear Systems	APPM 2360, ECEN 2260	
3320	Semiconductor Devices	ECEN 3250	
3400	Electromagnetic Fields and Waves	APPM 2350, ECEN 2260, PHYS 1110	
3410	Electromagnetic Waves & Transmission	ECEN 3400	
3810	Introduction to Probability	APPM 2350, APPM 2360	
4106	Photonics	ECEN 3300, PHYS 2130	
4138	Control Systems Analysis	ECEN 3300	
4167	Energy Conversion 2	ECEN 3170	
4242	Communication Theory	ECEN 3300, ECEN 3810	
4345	Introduction to Solid State	ECEN 3400	
4375	Microstructures Laboratory	ECEN 3320	
4517	Power Laboratory	ECEN 3170	
4532	DSP Laboratory	ECEN 3300, ECEN 4632 (co-req)	
4553	Introduction to Compiler Construction	ECEN 2120	CSCI 4555
4583	Software Systems Development	CSCI 2270	
4593	Computer Organization	ECEN 2120, ECEN 3100	CSCI 4593
4606	Optics Laboratory	ECEN 3400 *or* PHYS 4510	
4610	Capstone Laboratory	ECEN 2120, ECEN 2250, ECEN 2260, ECEN 3100, ECEN 3250, ECEN 3300, ECEN 3400, ECEN 3810, and ECEN 4593 (ECE majors only)	
4613	Embedded Systems Design	ECEN 2120, ECEN 3100 (ECEN 3250, ECEN 4593 recommended)	
4623	Real-Time Embedded Systems	ECEN 2120, ECEN 3100, (ECEN 4613 recommended)	
4632	Introduction to Digital Filtering	ECEN 3300	
4633	Hybrid Embedded Systems	ECEN 2120, ECEN 3100, ECEN 4593	
4634	Transmission Laboratory	ECEN 3410	
4638	Control Systems Laboratory	ECEN 3300, ECEN 4138(co-req)	
4645	Introduction to Optical Electronics	ECEN 3410	
4652	Communication Laboratory	ECEN 4242 (co-req)	
4703	Discrete Mathematics	ECEN 2120, ECEN 3810	
4797	Introduction to Power Electronics	ECEN 3250	
4811	Neural Signals and Functional Brain Imaging	ECEN 2260 or equiv.	ASEN 4216
4821	Neural Systems and Physiological Control	ECEN 2260 or equiv.	ASEN 4426
4827	Analog IC Design	ECEN 3250	
4831	Brains, Minds, and Computers	ECEN 2260	ASEN 4436

See prerequisite chart on the following page

Prerequisites for ECEN Program Courses

Prerequisite courses --->	APPM 1350	APPM 1360	APPM 2360	APPM 2350	PHYS 1110	PHYS2130	CSCI 1300	CSCI 2270	ECEN 2120	ECEN 2250	ECEN 2260	ECEN 3100	ECEN 3250	ECEN 3300	ECEN 3400	ECEN 3810	ECEN 3170	ECEN 3410	ECEN 3320	ECEN 4593	ECEN 4632	ECEN 4613	ECEN 4138	ECEN 4242	Notes
APPM 1350																									none
APPM 1360	X																								
APPM 2360	X	X																							
APPM 2350	X	X																							
CSCI 1300																									none
CSCI 2270							X																		
PHYS 2130	X	X	X	X	X					X					X										
ECEN 1100																									none
ECEN 1400	C																								
ECEN 2120							X																		
ECEN 2250	X	X	C																						
ECEN 2260	X	X	X							X															
ECEN 3100							X		X																
ECEN 3170	X	X	X							X	X		X												
ECEN 3250	X	X	X							X	X														
ECEN 3300	X	X	X							X	X														
ECEN 3320	X	X	X							X	X		X												
ECEN 3400	X	X	X	X	X																				
ECEN 3410	X	X	X	X	X										X										
ECEN 3810	X	X	X	X																					
ECEN 4106	X	X	X	X	X	X				X	X			X	X										
ECEN 4138	X	X	X							X	X			X											
ECEN 4167	X	X	X							X	X		X				X								
ECEN 4242	X	X	X	X						X	X			X		X									
ECEN 4345	X	X	X	X	X										X										
ECEN 4375	X	X	X							X	X		X						X						
ECEN 4517	X	X	X							X	X		X				X								
ECEN 4532	X	X	X	X						X	X			X		X					X				
ECEN 4553							X		X																
ECEN 4583							X	X																	
ECEN 4593							X		X			X													
ECEN 4606	X	X	X	X	X										X										*1
ECEN 4610	X	X	X	X	X		X		X	X	X	X	X	X	X	X				E					
ECEN 4613	R	R	R				X		X	R	R	X	R							R					
ECEN 4623							X		X			X										R			
ECEN 4632	X	X	X	X						X	X			X		X									
ECEN 4633							X		X			X								X					
ECEN 4634	X	X	X	X	X										X			X							
ECEN 4638	X	X	X							X	X			X									C		
ECEN 4645	X	X	X	X	X										X			X							
ECEN 4652	X	X	X	X						X	X			X		X								C	
ECEN 4703	X	X	X	X			X		X							X									
ECEN 4797	X	X	X							X	X		X												
ECEN 4811	X	X	X							X	X														*2
ECEN 4821	X	X	X							X	X														*2
ECEN 4827	X	X	X							X	X		X												
ECEN 4831	X	X	X							X	X														

C = corequisite
E = ECE majors only
R = recommended

*1 = may sub PHYS 4510 for ECEN 3400
*2 = or equivalent to ECEN 2260 (ECON 3030, MCEN 3017)

Choosing Theory and Elective Courses

It's true. The body of knowledge under the umbrella of Electrical Engineering is far too large to be obtained in only four years of college. And because of the appearance each year of new technologies, new tools, and new opportunities, the disparity gets ever larger. But this is not a matter of concern; it is merely the inevitable consequence of healthy growth in the profession.

Since its infancy in the 19^{th} century, Electrical Engineering has provided three legs to hold up modern society: Communication, Power, and Computation. But we do not rest on our laurels - the future remains bright: *Electrical Engineering is still in its adolescence*. In light of where the profession has been and how deeply it has changed society, to say that maturity is still in the future is a bold assertion. But we make it with complete confidence.

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. But because the range of application is so large it is necessary for you to sample some areas of specialization. A Guide has been prepared to help you select upper division (primarily senior level) courses in areas of interest in which you might eventually specialize. The areas chosen reflect the individual research interests and expertise of our faculty; and faculty members in each area have written the one-page descriptions.

Should you develop an appetite for further study, or would like to be involved in some independent work, you should consult one or more of the faculty listed. Finally, be sure to consult the current University Course Catalog for course descriptions - Graduate courses have not been listed, although there are usually several in each area.

The Guide can be found in the Appendix of this HELP! Guide and is also available as a separate handout. Following the description pages you will find a table showing in which semester you will find several of the theory and lab courses. Theory and lab courses are offered in either fall or spring and some are not offered every academic year. Be sure to check with the academic advisor for course availability.

Humanities and Social Sciences Requirements

Students must complete a 18 credit hours in approved courses in the Humanities and Social Sciences *and* 3 credit hours in approved, upper division writing courses.

A. **Writing**: 3 credit hours in one of the following upper division courses: WRTG 3030, WRTG 3035, GEEN 3000, HUEN 3100, or other writing courses as approved by petition.

B. **H&SS**: 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:

1) Any course included in any of the following eight of the eleven categories of courses in the Arts &Sciences Core found from the A&S Core Curriculum web page and through the PLUS system:
   a) Contemporary Societies
   b) Critical Thinking
   c) Culture & Gender Diversity
   d) Foreign Language
   e) Historical Context
   f) Ideals and Values
   g) Literature and the Arts
   h) United States Context

Exceptions: Critical Thinking courses taught in the following departments do NOT count for H&SS credit: ASTR, CHEM, EBIO, MATH, MCDB, PHYS.

2) The College is eager to see meaningful groupings of courses in related subjects and hence will approve H&SS electives, even if they are not courses in the A&S Core, when they are grouped so as to form a coherent plan of study. Prior 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 & Sciences: Economics, Ethnic Studies, History, Linguistics, Philosophy, Political Science, Religious Studies, or Women's Studies.

3) All courses taught through the Herbst Program of Humanities for Engineers and have "HUEN" as their prefix are approved. See the description of the Herbst Program below.

4) Any exceptions must be approved by petition to the department.

For assistance in planning see http://engineering.colorado.edu/homer/

Herbst Program for Humanities

The centerpiece of the Herbst Program is a two-semester 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, o*riginal 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, see http://engineering.colorado.edu/herbst/

ARE YOU GRADUATING?

To be eligible for a Bachelor of Science degree from this Department, you must meet the following requirements:

1. 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 after admission to the College of Engineering and Applied Science as a degree student unless exempted by prior petition.

2. Achieve a cumulative grade point average of 2.00 or better in all courses taken at the University of Colorado (all campuses) as well as a grade point average of 2.00 or better in all courses taken from, or cross listed in, the Department of Electrical and Computer Engineering.

3. 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.

4. Meet with the Undergraduate Staff Advisor the semester prior to the semester of intended graduation for a comprehensive review and approval of remaining courses needed to satisfy graduation requirements.

5. Notify the ECE department and the Engineering Dean's Office of your intent to graduate by filling out an Application for Diploma Card in the office of the Undergraduate Staff Advisor. This needs to be done at the beginning of your final semester.

6. If you are completing a minor, a Minor Completion form must be submitted to the Undergraduate Staff Advisor's Office.

7. A graduation list is posted near the Dean's Office (AD 110) and the ECE Undergraduate Office (EE 1B51) about a month after the beginning of each semester. Students intending to graduate should make certain that their names are listed. Any omissions or changes should be reported to both the Dean's Office and the ECE Undergraduate Office as soon as possible.

8. Obtain the recommendation of the ECEN faculty and the College faculty. This is handled by the department and college staff. You will be notified if you have not been recommended and the specific reasons.

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

Advising Resources

There are a vast number of advising resources available to students at CU-Boulder, but students frequently do not know about them. Please do not hesitate to contact any of these places for assistance.

Electronic Advising System
The advising system used by the ECE department to track student progress is Degreement by Optioventory. Use your IdentiKey login to access the system. The web address is https://ece.colorado.edu/gmsas/. This system provides a degree audit, planning, and more.

College of Engineering Advising Guides
These College guides, published by the Engineering Dean's office, are a series of individual sheets which cover a wide range of topics, including everything from academic honesty and ethics to scholarships to descriptions of every degree program offered in the College. They are located in a wall-mounted display in the front hallway of the Engineering Center just southeast of the revolving doors. These guides are also available online at http://engineering.colorado.edu/students/advising.htm.

Engineering Peer Advocates Office
This office provides services which include academic advising, assistance with major selection, tutoring, and test files as well as providing general information about study skills, test anxiety, resume writing, study abroad opportunities and much more. The office is staffed by sophomores, juniors, and seniors who have been trained to answer questions about anything that may affect you as an engineering student. It is located in ECCR 263 (303-492-0828), and is open and free to all current and prospective engineering students.

Pre-Professional Advising Center
Located in Old Main, room 1B90 (303-735-3000), the advisors provide support services to all CU-Boulder students preparing for careers in the medical sciences, health professions, and law.

Career Counseling in Career Services
The professional career counselors can help students and alumni clarify career interests, values and work-related skills; explore potential careers and employers; and refine job seeking, interviewing, and resume preparation skills. They host Career Fairs and Internship Fairs, sponsor resume writing workshops, and hold mock interview sessions. Career Services is located in Willard Hall, Room 34 (303-492-6541), or you may visit their website at http://www.colorado.edu/careerservices/index.html

Career Services Online (CSO)
Search jobs and internship listings, apply for on-campus interviews, and get weekly e-mail updates about career events. Sign up at http://careerservices.colorado.edu

Counseling and Psychological Services: A Multicultural Center
This center provides a variety of programs and assistance to address general academic or personal issues. They are located in Willard Hall, room 134, or call 303-492-6766.

Multicultural Engineering Program (MEP)
The Multicultural Engineering Program is an academic excellence community dedicated to the success of multicultural and first generation students historically underrepresented in engineering and applied science. The MEP Resource Center serves as a central meeting place for forming study groups and networking while providing access to MEP staff, computer stations, and more. The MEP office is located in ECCE 100 (303-492-6606). For additional information please visit the website: http://www.colorado.edu/engineering/MEP/.

Women In Engineering Program (WIEP)
This program was created to recruit and retain women students in the College of Engineering and Applied Science. WIEP conducts activities and programs that help make the educational experience rewarding for all students. The office is located in ECCE 113A (303-492-0083). You can get further information about WIEP http://engineering.colorado.edu/wiep.

Personal Program Notes:

Program Enrichment Options

Certificate Programs
Biomedical Engineering Option
Concurrent BS/MS 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 the 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 systems offers students the hardware and software knowledge and skills needed to design and implement these systems. The curriculum consists of two core courses and one elective course from an approved list. The two core courses are:

ECEN	4613	Embedded System Design
ECEN	4623	Real-Time Embedded Systems

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

ECEN	4610	Capstone Laboratory
ECEN	4033	Software Engineering of Stand-Alone Programs
ECEN	4633	Hybrid Embedded Systems
ECEN	4583	Software Systems Development

Software Engineering
Experienced software professionals work in a field that has maintained a relentlessly rapid rate of change for decades making it impossible to stay current in all aspects of software engineering. Those with limited experience find that the challenges of work assignments exceed their preparation from most undergraduate degree programs. In a typical computer-related undergraduate curriculum, it is not possible to devote enough credit hours specifically to software engineering to address all of the aspects of engineering complex systems including, for example, design for maintainability, concurrency, and distributed systems. The professional certificate in software engineering covers the body of knowledge necessary to develop products more predictably and reliably for stand-alone programs as well as for software in more complex environments. The curriculum consists of three core courses:

ECEN	4033	Software Engineering of Stand-Alone Programs
		or
ECEN	4583	Software Systems Development
		and
ECEN	4043	Software Engineering of Multi-Program Systems
ECEN	4053	Software Engineering of Distributed Systems

International Engineering Certificate in German
This is a new undergraduate academic program established at CU-Boulder in 2003. It offers students enrolled in an engineering degree program the opportunity to obtain an interdisciplinary certificate in International Engineering and German. The program prepares engineers for a global economy through language, cultural awareness, and international work experience. Students who have had German language instruction in high school, as well as students with other language experience who would like to begin studying German may apply. If interested, please contact the Dean's Office at 303-492-5071, or visit the website at http://ecadw.colorado.edu/engineering/academics/german.htm.

Engineering, Science & Society Certificate
This is a new certificate available for College of Engineering students. Check with your advisor.

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 the website: http://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 (BMI)

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

ECEN	4811/5811	Neural Signals and Functional Brain Imaging
ECEN	4821/5821	Neural Systems and Physiological Control
ECEN	4831/5831	Brains, Minds, and Computers
ECEN	40x1/50x1	Special Topics in Biomedical Engineering

For more information on the content of the BMI-ECE courses and pre-medical studies in ECE contact Professor Howard Wachtel, wachtel@colorado.edu, OT 433. For specific advice on fitting the BMI Option into an existing ECE program contact the Undergraduate Staff Advisor.

Study Abroad Program

A very special opportunity is available to engineering students through the Office of International Education. Study Abroad Programs, usually undertaken in the student's junior year, have been established with several universities around the world offering technical as well as elective social science and humanities courses. In recent years, ECE students have gone to Germany, Italy, France, and England to study. Programs can be arranged for either one semester or one academic year.

A formal exchange program has been established with the University of East Anglia (UEA) in Norwich, England, and a number of students from both CU-Boulder and UEA have participated. Course equivalents have been established so that, before they travel, students know what courses they will be taking and exactly how the credits will count. No CU student has lost a single credit hour by participating in this particular exchange program.

In most cases, students going abroad are "registered" on the Boulder campus so they maintain all of the rights of a resident student, including financial aid. The exchange agreement with UEA stipulates that students pay tuition to their home universities; all CU-Boulder students pay the in-state rate. Therefore, even with travel costs included, it is only slightly more expensive for in-state students to spend a year in England than in Boulder and several thousand dollars less expensive for out-of-state students.

An international perspective will be increasingly important in the marketplace of the future. Students who are able to take advantage of such opportunities as studying abroad will have a distinct head start in the business world as well as a unique experience to offer future employers. The personal advantages of spending a year in a different cultural setting are immeasurable.

The Department strongly encourages all students to consider participating in the Study Abroad Program. All interested ECE students should contact the ECE Undergraduate Office prior to applying to the program. More information is available at the Office of International Education, Environmental Design Building, Room 92, 492-7741.

Semester at Sea

The semester at sea is a study abroad program designed to incorporate a global semester into your undergraduate curriculum. Administered through the Office of International Education, and managed by the University of Pittsburgh's Institute for Shipboard Education, students explore and learn valuable insights into the various societies visited and allows students to analyze and discuss their observations in formal classes on the shipboard campus. Set sail aboard the SS Universe Explorer each semester and summers.

Contact the Office of International Education for more information in the Environmental Design Building, Room 1B45, (303) 492-7741 or visit their website at http://www.colorado.edu/OIE/StudyAbroad/index.html

Concurrent BS/MS Program

Students with strong academic records who plan to continue in the Graduate School for a Master's 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 and Computer 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 ECE 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 ECE 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 ECE Department courses, and (iv) at least three (3) letters of recommendation must be provided by the applicant (at least two (2) must be from ECE faculty at UCB). Transfer students in place of requirement (i) above, must have taken at least two (2) of the core ECE 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 ECE 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 ECE 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 ECE 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 bases 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 ECE Graduate Coordinator, as many as six (6) credit hours of ECE Department courses at the 5000 level or above may be counted both toward the undergraduate degree requirements and the requirements for the MS degree. In theory, therefore, the minimum number of credits for the Concurrent BS/MS degree will be 152.

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 ECE Department Coordinator for Undergraduate Studies by the end of the third week of the first semester in which the student has been admitted into the program.

Personal Program Notes:

Other Information

Department Regulations and Other Useful Information
Other Important Publications
Miscellaneous Curriculum Notes
Minimum Academic Preparation Standards (MAPS)

Department Regulations and Other Useful Information

Students with questions concerning Departmental regulations and requirements should check with the Undergraduate Staff Advisor first. In some cases, Department regulations differ from those of the College of Engineering. Students should make themselves aware of the following regulations as well as the regulations in the College Advising Guides.

Advanced Placement/College-Level Examination Program

AP and CLEP credit is handled as transfer credit. For students who have taken an advanced placement course in high school and who make the required score in the College Entrance Examination Board's Advanced Placement examination, advanced placement and college credit will be granted if the subject would normally be part of the student's curriculum. If the student elects to take the equivalent college course, the credit for that course will replace the advanced placement credit. All advanced placement credit must be validated by satisfactory achievement in subsequent courses.

For a listing of AP examinations, score required for credit, and equivalent courses at CU-Boulder, please refer to the current University of Colorado at Boulder Catalog. You may also find this information at: http://www.colorado.edu/prospective/freshman/requirements/ap.html

Course Repetition

The University currently has in place a program to give students the opportunity to repeat courses in which they received a grade of D+ or lower. Once completed, the original grade will be removed from both total credit hour and GPA computations; however, it will remain on the student's transcript. Students may use this program for a maximum of 10 credit hours. Info is at http://registrar.colorado.edu/students/registration/course_forgiveness.html. This is not available for independent study. A course in which a grade of C- or better has been received may not be repeated. **A student is not permitted to enroll in a course offered by the College when that course has not been successfully completed on three prior attempts.** If it is a course required for the degree, you will be dropped from the program.

Discovery Learning Apprenticeships

Undergraduate students are encouraged to apply for the opportunity to conduct research via a Discovery learning apprenticeship. Students can earn an hourly wage while engaging in research with college faculty and graduate students. Positions are announced in April for the following fall term and spring term. Students must apply and selection for positions is competitive. For more information, an application and a list of current discovery learning projects visit http://engineering.colorado.edu/activelearning/discovery.htm.

Double Degrees

It is possible to obtain bachelor's degrees in two engineering disciplines or one in EE (or ECE) and one in a second degree. Students must satisfy curricula for both programs and complete a minimum of 30 additional hours beyond the largest minimum required by either program.

Of the 30 additional semester credit hours, double degree students must complete 24 semester credit hours in courses offered by the secondary academic department or in courses approved in advance by the department as substitutes. Transfer students pursuing double degrees must complete a minimum of 75 semester credit hours as a degree student in the College of Engineering and Applied Science and must satisfy all other stipulations regarding total hours required and approval of all coursework by both departments concerned.

E-Mail Communication

E-mail is an official means of communication within the CU-Boulder community. Therefore, the University has the right to send communication to students via e-mail and expect that those communications will be received and read in a timely fashion. The campus recommends checking e-mail once per week, at minimum, because some communications may be time critical.

Additionally, the department maintains e-mail lists for communication with its students. You will be automatically placed on this list when you are accepted into the department. If you wish to be removed from this list, contact the Undergraduate Staff Advisor.

Engineering Management Courses

Engineering Management courses equip students with technical management expertise. Areas of technical management emphasis are in quality and process, research and development, operations, and project management. Engineering Management courses may be used to satisfy technical elective requirements for a B.S. degree up to a maximum of 6 credit hours.

Free Electives

The curriculum includes a maximum of 6 credit hours of free electives. Free electives may be any course that covers different material than other courses the student has taken. For example, a student may not take APPM 1350 Calculus 1 for Engineers and MATH 1300 Analytic Geometry/Calculus and receive credit for both.

Grades

Faculty within this College have the option of awarding grades with a plus (+) or minus (-) designation, except for A+. Faculty who teach courses have complete authority for calculating and assigning final grades in courses they teach. A final grade of "D-" or better in a course is sufficient to satisfy degree requirements unless the course is a prerequisite for another course in the student's program (see Prerequisite Requirements).

GPA

In addition to other University requirements, each student must satisfy the following at the time of graduation:
a cumulative grade point average of 2.00 in all courses taken on any campus at the University of Colorado;
a cumulative grade point average of 2.00 in all departmental courses (labeled ECEN xxxx or cross-listed with ECEN) taken on any campus at the University of Colorado. "Courses taken" means all courses for which a letter grade has been received, including all grades for repeated courses.

Graduate-Level Courses

Courses at the ECEN or CSCI 5000-level are closed to undergraduates with a GPA of less than 2.85 except by petition. Other campus departments may have different restrictions. Courses at the 6000-and 7000-level are closed to all undergraduate students. Graduate level courses applied towards the graduation requirement for the B.S. degree cannot be used again toward a graduate degree, either here or at another school. The only exception to this rule is students who are enrolled in the Concurrent BS/MS program. See the section about the Concurrent BS/MS program for further details.

Graduation Check

Each student should make an appointment with the Undergraduate Staff Advisor one semester prior to the semester in which he or she plans to graduate to review credits toward graduation. Even though all students are invited to review credits several times throughout their studies, this final graduation check is mandatory. If a student has not been through the graduation check and problems are found at graduation, an extra semester may be necessary.

Graduation Requirements

A complete listing of all requirements for graduating from the department of Electrical and Computer Engineering is in the section titled "Graduation Requirements" on a separate page in this *HELP! Guide*.

Honors

Students with cumulative GPA between 3.75 and 3.89 at the end of the semester prior to graduation will be awarded the designation "With Distinction" on their diploma. A GPA of 3.90 or higher earns the citation "With High Distinction." At least 50 hours must have been earned at the Boulder campus and grades earned during the semester of graduation will not be considered.

Eligible students are also encouraged to participate in the College of Arts and Sciences Honors Program. Criteria for the designations of cum laude, magna cum laude, and summa cum laude are set by the Honors Council and are recorded on the student's diploma and in the commencement program. This is a separate program and both distinction and cum laude can be earned. Interested students should consult with the Director of the Engineering Honors Program for detailed information.

GPA for cum laude is 3.700, for magna cum laude is 3.800 and for summa cum laude is 3.900.

Independent Study

Upper division independent study (ECEN 3840/4840) may be used as a technical elective to fulfill graduation requirements without petitioning. If it is used to fulfill any other requirement, it must be approved ahead of time by petition. Any Independent Study course sponsored by a faculty member in another department must be approved by petition and may not be used to fulfill the senior theory or lab requirements.

If interested, an *Independent Study Agreement* form must be completed and signed by both the student and the sponsor of the Independent Study or Undergraduate Research. These forms are available from the Undergraduate Staff Advisor and also on the ECE website. Students should use the faculty list section of this *HELP! Guide* to determine what faculty to contact.

No Credit and Pass/Fail

A course taken for no credit or pass/fail cannot be used for fulfilling graduation requirements. Once a course has been taken for no credit it cannot be repeated for a grade. Students are still subject to course tuition and fee expenses when registering for a course with the NC option.

Petitions

Any exceptions to department or college rules must have prior approval by petition. All petitions must be submitted to the Undergraduate Staff Advisor for departmental approval. Petitions involving exceptions to College rules will then be submitted to the Dean's Office for approval. It is the student's responsibility to find out if a petition has or has not been approved. Blank petition forms are available from the Undergraduate Staff Advisor, online on the ECE website, and the Dean's Office (AD 100).

Prerequisite Requirements

The minimum passing grade for a course that is considered a prerequisite for another required course is C-. If a grade of D+ or lower is received in a course which is prerequisite to another, the student is required to repeat the course until the minimum acceptable course grade has been earned. However, no course may be repeated more than thee times. If a student takes the advanced course, it does not remove the obligation to repeat the prerequisite course, even if the grade earned in the advanced course is a C- or above. The minimum passing grade for a course that is not specifically a prerequisite for another required course is D-. See the list on page 13 or the chart on page 14 for prerequisite courses. Also see the section on *Course Repetition* for rules on repeating courses.

ROTC

Students participating in the ROTC program may receive up to twelve (12) semester hours of credit toward fulfilling ECEN BS degree requirements from approved ROTC coursework (6 hours of Free Elective, 6 hours of Humanities/Social Science Elective).

Telecommunications Courses

The graduate Telecommunications Program offers special courses, most of which are usually not suitable as technical electives in the departmental programs. Therefore, a student may use only that Telecommunications course for which he or she has received prior approval, by petition, in his or her degree program. Only one approved Telecommunications course may be applied to the B.S. program. A brochure listing courses offered in the Telecommunications Program may be obtained in the Telecommunications Office (OT 313).

Transfer Credits

The initial transfer credit evaluation is performed by the Office of Admissions upon receiving an official transcript mailed directly from the institution where the credit was earned. Once the Office of Admissions has completed their evaluation, the ECEN Transfer Credit Evaluator, Professor Edward Kuester, ECOT 248, can verify the specific courses that apply to the Department's curriculum. Just because the Office of Admissions accepted the credit doesn't mean ECEN will utilize that credit toward BS degree requirements. The Office of Admissions will not accept course work in which the student received a grade lower than a C-. Nor will Pass/Fail credit be accepted. Credits from an Engineering Technology program normally will not transfer, and no academic credit is normally given for work or co-op experience. Credit received more than 10 years prior to admission will be accepted.

All transfer students should see the Department's Transfer Credit Evaluator, Professor Edward Kuester, ECOT 248, about acceptance of transfer credits before classes begin. Acceptance of transfer credits is provisional for one academic year following admission to the ECE Department and until academic competence in subsequent courses has been established. (Those transferring here from UCD or UCCS are *not* considered transfer students, but they should review their credits with the Undergraduate Staff Advisor in order to determine how credits received at another campus will fit into this program.)

Transfer students should understand that all credits received at other universities may not – in fact, most likely will not –apply toward their ECE program. Transfer credits are first reviewed by the University, which accepts those it feels are comparable to courses at CU. Then that list of courses is reviewed by the Transfer Credit Evaluator who approves only those courses which are comparable to courses required by departmental curricula. In most cases, this is only a fraction of total transfer hours.

The number of credit hours for each course may vary by institution and final grades do not transfer between institutions. Also, the completion of these courses does not assure the student of acceptance into an engineering degree program; each institution has its own admission criteria. Lower division courses cannot transfer as upper division courses between two-year and four-year institutions.

Once the Transfer Credit Evaluator has approved transfer hours, the student should deliver a copy of the signed sheet to the Undergraduate Staff Advisor in the Undergraduate Office to be made a part of his or her departmental file.

45-Hour Rule

Students graduating from CU-Boulder must complete their last 45 hours on the Boulder campus or through CAETE (Center for Advanced Engineering & Technology Education). Courses taken through Continuing Education or by correspondence, even though registered for in Boulder, are *not* considered Boulder campus courses. Any exceptions to the 45-hour rule must be approved by petition *in advance* before registering or they will not be counted toward the degree.

OTHER IMPORTANT PUBLICATIONS

University of Colorado Catalog	Degree requirements, academic standards, administrative regulations, university policies and procedures (dry and dull, but important). http://www.colorado.edu/catalog/
College Advising Guides	College of Engineering requirements, rules, regulations (must read). http://ecadw.colorado.edu/engineering/students/advising.htm
Ralphie's Guide to Student Life	A-Z listing of university resources, facilities, and special programs as well as rules, regulations, and policies (wealth of well-organized, entertaining information). http://www.colorado.edu/ralphie/

MISCELLANEOUS CURRICULUM NOTES

- The curricula listings on pages 7 and 9 are not a misprint: It is highly recommended that you take APPM 2360 (Linear Algebra and Differential Equations) before APPM 2350 (Calculus 3). Material covered in APPM 2360 will help you with Circuits 1 and must be taken as a co-requisite.
- WRTG 3035, GEEN 3000, or HUEN 3100 will substitute for WRTG 3030.
- APPM 2380 plus APPM 2480 will substitute for APPM 2360.

MINIMUM ACADEMIC PREPARATION STANDARDS (MAPS)

All students entering the University of Colorado who finished high school in the spring of 1988 or thereafter must meet Minimum Academic Preparation Standards specified by each school or college. The College of Engineering and Applied Sciences has adopted the following standards for admission. These standards are defined in high school units. A unit is one academic year of course work.

1. English 4 units
2. Mathematics 4 units (including 2 algebra, 1 geometry, and 1 college prep, eg. trigonometry)
3. Natural Science 3 units (including 1 unit in chemistry and 1 unit in physics)
4. Social Science 2 units
5. Foreign Language 3 units (of the same language) (as of Fall 2007)

Policies Concerning MAPS Deficiencies

Students who are admitted to the College of Engineering with a deficiency in one or more of the above categories are required to complete the appropriate courses through courses taken at CU-Boulder or other institutions of higher education or approved credit-by-examination programs *prior to their graduation from college*.

The policies of the Boulder campus with respect to completing MAPS course work after enrollment are as follows:

1. Appropriate missing MAPS course work may be included in the hours for graduation.

2. All course work taken to fulfill MAPS deficiencies must be taken for a letter grade.

3. Students are required to enroll in and complete at least one MAPS course each term, beginning in the first term of enrollment, until all MAPS units are completed. This policy applies to new freshmen, to transfer students, and to students transferring from other academic units on the Boulder campus and from other campuses of the University. Failure to comply with this requirement may result in suspension at the end of the term in which the student ceases taking courses to complete missing MAPS units.

4. All students who first enroll in one academic college or school at CU-Boulder and who subsequently transfer to another college or school are required to meet the MAPS specified for the new unit, irrespective of their completion of MAPS units in their previous college or school.

5. Students in double-degree programs must meet MAPS requirements of both degree-granting programs.

6. Students must consult with a CU-Boulder academic advisor (or read their college's academic survival guide) to determine which specific courses may be used to meet a MAPS requirement.

7. Students who graduate from a foreign high school are exempt from MAPS requirements.

Appendix

Faculty Directory
Theory and Elective Areas of Interest Descriptions
Theory and Lab Combinations Chart
EE Advisor's Grid
ECE Advisor's Grid

Electrical and Computer Engineering Teaching Faculty

Area code 303

Professor	***Office***	***Telephone***	***E-mail***	***Area of Interest***
James Avery	OT 240	492-6310	avery@colorado.edu	Computer Engineering
Susan Avery	CIRES 309	492-7653	savery@colorado.edu	Remote Sensing
Frank Barnes	OT 250	492-8225	barnes@colorado.edu	Bioengr, Nanostructures
Timothy Brown	OT 256	492-1630	timxb@colorado.edu	Sig. Proc., Comm.
Thompson Brown	EE 1B22	492-4190	tomb@colorado.edu	Capstone Laboratory
Daniel Connors	OT 342	735-7199	dconnors@colorado.edu	Computer Engineering
Ruth Dameron	OT 435		dameron@colorado.edu	Computer Engineering
Robert Erickson	OT 356	492-7003	rwe@colorado.edu	Power Electronics
Dejan Filipovic	OT 243	735-6319	dejan@colorado.edu	Electromagnetics
Ewald Fuchs	OT 340	492-7010	Ewald.Fuchs@colroado.edu	Power Electronics
Albin Gasiewski	OT 246	492-9688	Al.Gasiewski@colorado.edu	Electromagnetics
John Hauser	OT 437	492-6496	hauser@colorado.edu	Dynamics & Controls
Vincent Heuring	EE 1B55	492-8751	heuring@colorado.edu	Computer Engineering
Edward Kuester	OT 248	492-5173	kuester@colorado.edu	Electromagnetics
Michael Lightner	EE 1B55	492-5180	lightner@colorado.edu	VLSI/CAD
Eugene Liu	OT 337	735-6307	liue@colorado.edu	Sig. Proc., Comm.
Dragan Maksimovic	OT 346	492-4863	maksimov@colorado.edu	Power Electronics
Peter Mathys	OT 334	492-7733	mathys@colorado.edu	Sig. Proc., Comm.
Linden McClure	EE 2B37		mcclure@colorado.edu	Computer Engineering
Robert McLeod	EE 1B47	735-0997	mcleod@colorado.edu	Optics & Photonics
David Meyer	OT 438	492-7158	dgm2r@colorado.edu	Dynamics & Controls
Francois Meyer	OT 251	492-5470	fmeyer@colorado.edu	Bioengr., Comm.
Alan Mickelson	EE 130	492-7539	mickel@colorado.edu	Optics, EM.
Richard Mihran	OT 436	492-8375	mihran@colorado.edu	Bioengineering
Garret Moddel	EE 148	492-1889	moddel@colorado.edu	Nanostructures & Devices
C.T. Mullis	OT 335	492-8718	mullis@colorado.edu	DSP, Communication
Todd Murphey	OT 332	492-1090	murphey@colorado.edu	Dynamics & Controls
William Newhall	OT 434	735-2287	newhallw@colorado.edu	
Lucy Pao	OT 350	492-2360	pao@colorado.edu	Dynamics & Controls
Wounjhang Park	EE 248	735-3601	wpark@colorado.edu	Nanostructures & Devices
Rafael Piestun	EE 246	735-0894	piestun@colorado.edu	Optics & Photonics
Melinda Piket-May	OT 242	492-7448	mjp@colorado.edu	Electromagnetics
Andrew Pleszkun	EE 1B67	492-3571	arp@colorado.edu	Computer Engineering
Zoya Popovic	OT 252	492-0374	zoya@colorado.edu	Electromagnetics
Samual Siewert		542-2508	siewerts@colorado.edu	Computer Engineering
Fabio Somenzi	OT 348	492-3466	Fabio@colorado.edu	VLSI/CAD
Manish Vachharajani	OT 336	492-0612	manishv@colorado.edu	Computer Engineering
Bart VanZeghbroeck	EE 1B41	492-2809	bart@colorado.edu	Nanostructures & Devices
Mahesh Varanasi	OT 333	492-0258	varanasi@colorado.edu	Sig. Proc., Comm.
Howard Wachtel	OT 433	492-7713	wachtel@colorado.edu	Bioengineering
Kelvin Wagner	EE 233	492-4661	Kelvin@colorado.edu	Optics & Photonics
Regan Zane	OT 352	735-1560	Regan.zane@colorado.edu	Power Electronics

Guide to Choosing Theory and Elective Courses

COMMUNICATIONS

ECEN 4242 - Communication Theory
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

ECEN 4632 – Digital Filtering
ECEN 4532 – Digital Signal Processing Laboratory

Faculty advisors: F. Meyer, C. T. Mullis, E. Liu

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

ELECTROMAGNETICS, RF AND MICROWAVES

ECEN3410 – Electromagnetic Waves and Transmission
ECEN4634 – Transmission Laboratory

Faculty advisors: E. Kuester, Z. Popovic, A. Gasiewski, M. Piket-May, D. Filipovic

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.

Some Technological Problem Areas

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

Some Societal Problem Areas

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

MICROELECTRONICS

ECEN 4797 – Introduction to Power Electronics
ECEN 4517 – Power Electronics Laboratory
ECEN 4827 – Analog IC Design

Faculty advisors: R. Erickson, D. Maksimovic, R. Zane

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. ECEN2250, ECEN2260 and ECEN3250 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.

Technical areas

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

Societal Impact areas

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

NANOSTRUCTURE MATERIALS & DEVICES TRACK

PHYS 1120 – Physics 2 (Electricity & Magnetism) (recommend spring freshman yr)
ECEN 4345 – Introduction to Solid State (recommend spring junior yr)
ECEN 3320 – Semiconductor Devices (recommend fall senior yr)
ECEN 4375 – Microstructures Laboratory (recommend spring senior yr)

Faculty advisors: F. Barnes, G. Moddel, B. Van Zeghbroeck, W. Park

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 1120 Physics 2** early. The stepping-off point to junior and senior-level nanostructures courses is **ECEN 3250 Circuits/Electronics 3**. After that **ECEN 4345 Intro to Solid State** and **ECEN 3320 Semiconductor Devices** can be taken in any order, but it may be helpful to take Intro to Solid State first, even though it is currently listed as a 4000-level course. Semiconductor Devices must be taken before Microstructures Laboratory. **ECEN 4375 Microstructures Laboratory** provides hands-on experience with designing and fabricating working microelectronic devices learned about in Semiconductor Devices.

Some Technological Problem areas

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

Some Societal Problem areas

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

NEURAL AND BIOMEDICAL ENGINEERING

ECEN 4831 – Brains Minds and Computers
ECEN 4821 – Neural Systems and Physiological Control
ECEN 4811 – Signals and Functional Brain Imaging
ECEN 480x -- Special Topics in BME (e.g. Bioelectromagnetics)

Faculty advisors: H.Wachtel, F.Barnes, M.Lightner, F.Meyer, R.Mihran

The roots of electrical engineering and neuroscience both go back to the late 18^{th} 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, some say, Neurotechnology) and it is well represented in the course offerings open to junior and senior (as well as first-year graduate) ECE students. It is also comprises the major didactic component of the broader program in Biomedical Engineering (BME) that has been available, in several forms, to ECE students for over 20 years.

BME currently exists as an undergraduate ECE Option wherein elective credit is awarded for a full year of Biology (and a second semester of chemistry) if the student completes two semesters of the BME (Neural and otherwise) electives listed above. This BME option is particularly attractive to pre-medical school students or others who plan to pursue graduate studies (and/or careers) in BME or various biomedical sciences. The NE track however, would not subsume, or require, any previous coursework in Biology and would be aimed largely at students who are pursuing the NE track in the context of an ECE education and career trajectory. So, the courses listed above, which can fulfill either (or both) the NE track and the BME option, are designed to be comprehensible to engineering students with no prior biological background.

Representative Technical and Scientific Problem Areas

Measurements of Biomedically Important Signals
Algorhythms for Biomedical Signal Processing and Display
Technologies for Imaging Body Anatomy (MRI, CAT, etc.)
Technologies for Imaging neuroelectric Activity Patterns (FMRI, etc.)
Methods for 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.

RENEWABLE ENERGY

ECEN 1000 Special Topics Energy 101
ECEN 3170 – Energy Conversion I,
ECEN 4167 – Energy Conversion II
ECEN 4517 – Power Laboratory

Faculty advisors: E.F. Fuchs, F.S. Barnes, M. J. Piket-May, R.W. Erickson, D. Maksimovic

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
- The 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

ROBOTICS AND CONTROL

ECEN 4138 – Control Systems Analysis
ECEN 4638 – Control Systems Laboratory

Faculty advisors: J Hauser, D Meyer, T Murphey, 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 (ECEN 3300) and the controls sequence early. If possible, students should take ECEN 3300 by their Spring sophomore term so that they can take ECEN 4138/4638 in their Fall junior 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.

Some Technological Problem areas

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

Some Societal Problem areas

Safe transportation
Precise medical treatment and rehabilitation
Efficient energy usage

Theory and Lab Combinations for EE/ECE Majors: PLAN AHEAD!!

Offered Fall ONLY

ECEN 4652 - Communication Lab

Fall or earlier------------------>	Spring or earlier----------->	Fall
ECEN 2260 - Circuits 2	**ECEN 3300** - Linear Systems	**ECEN 4652** - Communication Lab plus required co-requisite: **ECEN 4242** - Communication Theory

ECEN 3810 - Intro to Probability or alternative (APPM 3570 OR MATH 4510)

ECEN 4634 - Transmission Lab

Fall or earlier------------------>	Spring or earlier----------->	Fall
ECEN 3400 - EM Fields and Waves	**ECEN 3410** - EM Waves and Transmission	**ECEN 4634** - Transmission Lab

(Prereq for ECEN 3400 is ECEN 2260 - Circuits 2)

ECEN 4638 - Controls Lab

Fall or earlier------------------>	Spring or earlier----------->	Fall
ECEN 2260 - Circuits 2	**ECEN 3300** - Linear Systems	**ECEN 4638** - Controls Lab plus required co-requisite: **ECEN 4138** - Control Systems Analysis

ECEN 4606 - Undergrad Optics Lab

Fall or earlier------------------>	Spring or earlier----------->	Fall
ECEN 2260 - Circuits 2	**ECEN 3400** - EM Fields & Waves	**ECEN 4606** - Undergrad Optics Lab plus required co-requisite: **ECEN 4106** - Photonics

Offered Spring ONLY

ECEN 4532 - Digital Signal Processing (DSP) Lab

Spring or earlier----------->	Fall or earlier------------------>	Spring
ECEN 2260 - Circuits 2	**ECEN 3300** - Linear Systems	**ECEN 4532** - DSP Lab plus required co-requisite: **ECEN 4632** - Intro to Digital Filtering

ECEN 3810 - Intro to Probability or alternative (APPM 3570 OR MATH 4510)

ECEN 4517 - Power Electronics Lab

Spring or earlier----------->	Fall or earlier------------------>	Spring
ECEN 3250 - Circuits 3	**ECEN 3170** - Energy Conversion 1	**ECEN 4517** - Power Electronics Lab

ECEN 4375 - Microstructures Lab*

Spring or earlier----------->	Fall or earlier------------------>	Spring*
ECEN 3250 - Circuits 3	**ECEN 3320** - Semiconductor Devices	**ECEN 4375** - Microstructures Lab*

*Check with advisor

Offered both Fall and Spring

Counts as lab for EE majors only; tech elective for ECE
ECEN 4613 - Embedded Systems Design

Prerequisites
ECEN 2120 - Computers as Components ***AND*** **ECEN 3100** - Digital Logic
(**ECEN 3250** - Circuits 3 and **ECEN 4593** - Computer Organization recommended)

Offered both Fall and Spring

Counts as theory for EE majors only; tech elective for ECE
ECEN 4623 - Real-time Embedded Systems

Prerequisites
ECEN 2120 - Computers as Components ***AND*** **ECEN 3100** - Digital Logic
(**ECEN 4613** - Embedded Systems Design recommended)

Offered both Fall and Spring

Counts as lab for EE majors only; tech elective for ECE
ECEN 4633 - Hybrid Embedded Systems

Prerequisites
ECEN 2120 - Computers as Components ***AND*** **ECEN 3100** - Digital Logic ***AND***
ECEN 4593 - Computer Organization

EE Advisor's Grid

		Phys/Chem	Math	ECE/CS Required	Distribution Requirements	Technical Electives	Free Electives	Humanities & Social Sci	Sem Hrs
FRESHMAN	Fall	PHYS 1110-4 Physics 1	APPM 1350-4 Calculus 1	CSCI 1300-4 CS1: Programming				H&SS #1 - 3	16
				ECEN 1100-1 Freshman Sem					
	Spring	CHEN 1211-3 CHEM 1221-2 Chem w/ lab	APPM 1360-4 Calculus 2	Freshman Elective				H&SS #2-3	15
SOPHOMORE	Fall		APPM 2360-4 Lin Alg/Diff EQ	ECEN 2120-5 Computer/Comp				H&SS #3-3	17
				ECEN 2250-5 Circuits 1					
	Spring		APPM 2350-4 Calculus 3	ECEN 2260-5 Circuits 2				H&SS #4-3	17
				ECEN 3100-5 Digital Logic					
JUNIOR	Fall			ECEN 3300-5 Linear Systems			Course #1-2		15
				ECEN 3400-5 EM Fields					
				ECEN 3810-3 Probability					
	Spring	PHYS 2130-3 Modern Physics		ECEN 3250-5 Circuits 3			Course #2-3	WRTG 3030-3	17
				ECE Elective-3					
SENIOR	Fall			ECE Elective-3	Theory #1: ECEN 4____ or Unused ECE Elective	Course #1-3		H&SS #6-3	17
					Theory #2: ECEN 4____				
					Lab #1: ECEN 4____				
	Spring				Theory #3: ECEN 4____	Course #2-3		Upper Division H&SS #7-3	14
					Lab #2: ECEN 4____				
					ECEN 4610-3 Capstone Laboratory				
Hours Required		12	16	52	16	6	5	21	128

ECE Advisor's Grid

		Phys/Chem	Math	ECE/CS Required	Distribution Requirements	Technical Electives	Free Electives	Humanities & Social Sci	Sem Hrs
FRESHMAN	Fall	PHYS 1110-4 Physics 1	APPM 1350-4 Calculus 1	CSCI 1300-4 CS1: Programming				H&SS #1 - 3	16
				ECEN 1100-1 Freshman Sem					
	Spring	CHEN 1211-3 CHEM 1221-2 Chem w/ lab	APPM 1360-4 Calculus 2	Freshman Elective				H&SS #2-3	15
SOPHOMORE	Fall		APPM 2360-4 Lin Alg/Diff Eq	ECEN 2120-5 Computer/Comp				H&SS #3-3	17
				ECEN 2250-5 Circuits 1					
	Spring		APPM 2350-4 Calculus 3	ECEN 2260-5 Circuits 2				H&SS #4-3	17
				ECEN 3100-5 Digital Logic					
JUNIOR	Fall			ECEN 3300-5 Linear Systems					17
				ECEN 3400-5 EM Fields					
				ECEN 3810-3 Probability					
				CSCI 2270-4 CS 2: Data Structures					
	Spring			ECEN 3250-5 Circuits 3				WRTG 3030-3	14
				ECEN 4593-3 Computer Org					
				Software Elective					
SENIOR	Fall	PHYS 2130-3 Modern Physics			Theory ECEN 4____	Course #1-3	Course #1-3	H&SS #6-3	17
					Lab ECEN 4____				
	Spring			ECEN 4610-3 Capstone Laboratory		Courses #2-3	Course #2-3	Upper Division H&SS #7-3	15
				ECEN 4703-3 Discrete Math					
Hours Required		12	16	62	5	6	6	21	128

Index