ELECTRICAL AND COMPUTER ENGINEERING

Electrical and Computer Engineering
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The mission of the Department of Electrical and Computer Engineering (ECE) at the undergraduate level is to offer programs that support and complement the University mission; to provide a general undergraduate education in computer, electrical, and mechanical engineering that prepares students for employment or graduate study; to include interdisciplinary engineering work in all engineering programs; to encourage the professional status of the faculty; and to foster the professional awareness of the students. This statement concisely sums up the goals and objectives of our programs. All Engineering degrees are accredited by the Engineering Accreditation Commission (EAC) of ABET.[1]

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You will find information about the following topics below:

- Program Educational Objective
- Program Components
- Engineering Design
- Course of Study
- PINs and Undergraduate Research Assistantships
- Study Abroad
- Fundamentals of Engineering (FE) Exam & Enrollment as an Engineer-Intern (EI)

PROGRAM EDUCATIONAL OBJECTIVES

The undergraduate program objectives of the Electrical and Computer and Mechanical and Materials Engineering Departments are to produce graduates who, within a few years of graduation:

a. Apply their engineering and problem-solving skills towards engineering practice, engineering graduate school, or other fields such as medicine, science, business, or law.

b. Value and demonstrate character by acting responsibly, ethically, and professionally.

c. Work synergistically in diverse and global environments to positively impact society.

d. Embrace life-long learning to support professional development and personal wellness.

STUDENT OUTCOMES

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.

The students outcomes for the BS in Electrical Engineering or Computer Engineering program are:

a. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
b. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
c. an ability to communicate effectively with a range of audiences
d. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
e. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
f. an ability to develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions
g. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

PROGRAM COMPONENTS

The Departments of Electrical and Computer Engineering (ECE) and Mechanical and Materials Engineering (MME) work closely together to deliver an exceptional educational experience for our students and to advance the state of the art through research and industry collaborations.

All of our engineering programs have several components:

a. The University of Denver's Common Curriculum, which includes first-year seminar, writing courses, analytical inquiry and scientific inquiry courses, and advanced seminar

b. Basic sciences and mathematics, including chemistry, physics, and mathematics

c. An engineering common curriculum, with fundamental material from computer, electrical, and mechanical engineering

d. An engineering discipline (computer engineering, electrical engineering, mechanical engineering)

e. Multiple integrated design experiences, which are interdisciplinary and involve teams working on impactful real-world problems

f. Depth and/or breadth in the discipline through engineering, math, and science electives personalized to the student's individual interests.

ENGINEERING DESIGN

The feature of engineering programs that most differentiates them from programs in basic or applied science and mathematics is engineering design, which is both an art and a science. Our programs feature a four-year stem of course work required of all students, regardless of curriculum, which emphasizes design, project work, team-work, and the application of scientific and technical knowledge and design skills already acquired to the solution of interdisciplinary engineering problems. As the student progresses in the curriculum, more and more reliance is placed on previous work, and more realistic constraints and considerations are required for success. The sequence culminates in a three-quarter capstone design project carried out in the final year. Additional design work is contained in specialized courses.

COURSE OF STUDY

Engineering curricula are highly structured; acquisition of certain knowledge and skills must precede acquisition of more advanced ones. There is, thus, very little flexibility in the order in which courses must be completed, and there are few electives. Most engineering courses are offered only once a year, so an omission or deletion can add a year to the time required to complete the degree program. Although a high percentage of our students graduate in four years, it should be noted that, nationwide, nearly half of all engineering graduates take more than four years to complete their degrees, so students should not become discouraged if this is needed. The additional year may also be used to acquire additional expertise.

Engineering Common Curriculum: The curricula in all programs are the same for the first 5 quarters; a student can delay choosing an engineering major until the beginning of the spring quarter of their second year.

Advanced Curriculum (Four Year Program):

The curricula for the last two years have several components:

a. Advanced work in the engineering discipline chosen;

b. Integrated engineering project work and design;

c. Development of a specialized area (details of the areas of specialization for each degree program are given later in this booklet);

d. Completion of the University of Denver Common Curriculum

Advanced Curriculum (Five-Year Dual-Degree (BS/MS) Program):

The curricula for the last three years have several components:

a. Advanced work in the engineering discipline chosen;
b. Integrated engineering project work and design;
c. Completion of the University of Denver Common Curriculum;
d. Completion of the requirements for the MS in the engineering discipline.

For more information on any of these programs, please contact an advisor from either Electrical and Computer Engineering or Mechanical and Materials Engineering. Students interested in these options should discuss them with an advisor as early as possible in their undergraduate careers. For further information regarding these programs, visit the ECE (http://ritchieschool.du.edu/departments/ECE) and MME (http://ritchieschool.du.edu/departments/MME (http://ritchieschool.du.edu/departments/mme/)) web sites.

PINS AND UNDERGRADUATE RESEARCH ASSISTANTSHIPS

Students wishing to participate in faculty research projects may be eligible for participation in PinS (Partners in Scholarship) or Undergraduate Research Assistantships (URA's). PINS is a University-wide program in which a student performs research in conjunction with a faculty member. More information on PINS is available at http://www.du.edu/urc/. URA's work directly with faculty, often for compensation, on current research efforts. Students can read about faculty research interests on the ECE (http://ritchieschool.du.edu/departments/ECE) and MME (http://ritchieschool.du.edu/departments/MME (http://ritchieschool.du.edu/departments/mme/)) web sites. Such work enhances the student's ability to compete for scholarships, internships, entrance to graduate study and permanent employment. A limited number of these are available and are typically restricted to upper-division students with good academic backgrounds. An agreement with a specific faculty member is required and the URA is requested by, and granted to, the faculty member.

STUDY ABROAD

The University of Denver strongly encourages students to participate in study abroad programs, particularly the Cherrington Global Scholars Program; more information about which can be found at: http://www.du.edu/intl/abroad/

The engineering curricula have been structured so that students may take advantage of this opportunity in the autumn quarter of the senior year, rather than in the autumn quarter of the junior year, as is more usual in other DU programs.

Engineering students must be especially careful in planning this experience because of the highly restrictive and sequential nature of engineering curricula. It should also be noted that the abroad sites at which the required courses can be found are limited, vary depending on degree, and may change from one year to the next. Drs. Matt Gordon and David Gao are the department contacts for students interested in the Cherrington Global Scholar Program.

COOPERATIVE EDUCATION PROGRAM

Recognizing the value of experiential learning, we have created a paid co-op program which is optional and competitive for all Ritchie School students, though ideally suited for current sophomores and juniors. Through this collaborative program between academia and industry, students work full time at participating companies earning valuable work experience. Typically, students will not take classes for one full academic year, resuming their studies upon their return exactly in sequence but one year removed. In some cases, DU courses can be taken while on co-op. Dr. Matt Gordon is the department contact for students interested in the co-op program.

FUNDAMENTALS OF ENGINEERING (FE) EXAMINATION AND ENROLLMENT AS AN ENGINEER-INTERN (EI)

The FE Exam is optional for all electrical and computer engineering students, but highly recommended. The FE Exam is the first of a two-step process in order to become registered as a Professional Engineer (PE).

The FE exam is a national 6-hour examination administered by NCEES (National Council of Examiners for Engineering and Surveying) in conjunction with the Colorado State Board for Professional Engineers and Land Surveyors. Students must have completed at least 135 credits to apply to take the FE exam, for which a fee is charged. For more information please contact the ECE department chair.

After passing the FE exam, the student must send a final transcript recording the receipt of an engineering degree to the Colorado State Board for Professional Engineers and Land Surveyors. Typically, after passing the FE exam, the requirements for registration as a PE are 4 years of engineering experience under the supervision of a PE with increasing engineering responsibility and passing the PE examination.

Criteria for Entering Any of the Engineering Programs

In the first year, students should plan to take the following:

MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
MATH 1953	Calculus III	4
PHYS 1211	University Physics I	5
PHYS 1212	University Physics II	5

Students lacking the mathematics preparation to begin calculus in the first quarter may take MATH 1070 College Algebra and Trigonometry followed by the usual calculus sequence; these students should meet with an advisor from the engineering department before enrolling for courses. Failure to complete the courses listed above in the first year may lead to an additional year of study.

Minors in Engineering for Non-Engineering Students

Students desiring to minor in any of the engineering disciplines must take 20 hours of discipline specific engineering courses in addition to the equivalent of MATH 1951 Calculus I, MATH 1952 Calculus II, and MATH 1953 Calculus III. It is recommended that they have PHYS 1211 University

Physics I, PHYS 1212 University Physics II, and PHYS 1213 University Physics III in their curriculum. Degree programs that “naturally flow” into an engineering minor are: chemistry, computer science, biology, mathematics and physics.

Computer Engineering

Bachelor of Science in Computer Engineering Requirements

(192 credits required for the degree (http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofscienceincomputerengineering/))

This degree requires a minimum of 192 credits. Students not in the BSCPE/MBA combined program select a specialty area from communications, digital signal processing and networking; robotics, embedded systems and instrumentation, and computer systems engineering; or, under special circumstances, an individualized specialization may also be approved. Faculty mainly associated with computer engineering pursue research in microprocessors, microsystems, biomedical systems, computer architecture, complex VLSI systems design, digital systems modeling and simulation, networks, parallel and distributed control, and processing.

Requirements

192 credits are required for the degree including 48 credits of mathematics and basic science, 75 - 83 credits of engineering topics, and additional credit in computer science.

Code	Title	Credits
ENCE 2101	Digital Design	3
ENCE 3100	Advanced Digital System Design	4
ENCE 3210	Microprocessor Systems I	4
ENCE 3260	Python for Engineers	3
ENCE 3231	Embedded Systems Programming	4
ENCE 3501	VLSI Design	3
ENEE 2012	Circuits I and Laboratory	4
ENEE 2022	Circuits II	4
ENEE 2211	Electronics	4
ENEE 3111	Signals & Systems	4
ENGR 1511	Engineering Connections	1
ENGR 1572	Applied MATLAB Programming	3
ENGR 1611	Introduction to Engineering Design	4
ENGR 1622	Introduction to Mechatronic Systems I	4
ENGR 1632	Introduction to Mechatronic Systems II	4
ENGR 2610	Engineering Integration I	3
ENGR 2620	Engineering Integration II	3
ENGR 2950	Engineering Assessment I	0
ENGR 2951	Engineering Assessment II	0
ENGR 3100	Instrumentation and Data Acquisition	4
ENGR 3313	Engineering Design Project I	2
ENGR 3323	Engineering Design Project II	3
ENGR 3333	Engineering Design Project III	3
ENGR 3650	Probability and Statistics for Engineers	4
ENGR 2910	Engineering Economics and Ethics	3
ENME 2510	Statics with Lab	4
ENME 2541	Mechanics of Materials	3
Technical Electives		12

Notes

Technical electives are used to complete specializations for the degree. Only technical courses may be used, and these must carry upper-division credit. Prior approval by the advisor is required.

Additional Requirements

Chemistry

Code	Title	Credits
CHEM 1010	General Chemistry I	3
CHEM 1240	General Chemistry I Laboratory	1

Computer Science

Code	Title	Credits
COMP 1351	Introduction to Programming I	3
COMP 1352	Introduction to Programming II	3
COMP 1353	Introduction to Data Structures & Algorithms I	3
COMP 2300	Discrete Structures in Computer Science	4
COMP 2361	Systems I	4
COMP 2362	Systems II	4

Mathematics

Code	Title	Credits
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
MATH 1953	Calculus III	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4

Physics

Code	Title	Credits
PHYS 1211	University Physics I	5
PHYS 1212	University Physics II	5
PHYS 1214	University Physics III for Engineers	4

Notes

Students must take an additional one (1) mathematics or science course form the approved list (4 credit hours). See Degree Program Plan for Approved courses.

Please see advisor for the additional MATH/Sci and UCC requirements.

Areas of Specialization

All Bachelor of Science in Computer Engineering students are required to choose an area of specialization. The area of specialization can be fulfilled through the students choice of technical electives. The students must choose a minimum of 3 courses in one of the areas of specialization. For specific courses in the specialization areas, please see Degree Program Plan.

- **Communications, DSP, and Networking**
- **Computer Systems Engineering**
- **Robotics, Embedded Systems, and Instrumentation**
- **Individualized Option**

Nine credits of upper division technical courses selected with advisor's approval.

Minor Requirements for Computer Engineering

20 credits, including:

Code	Title	Credits
COMP 1351	Introduction to Programming I	3
ENCE 2101	Digital Design	3
ENEE 2012	Circuits I and Laboratory	4
Electives		

ENCE courses at the 2000-level or above	10
Total Credits	**20**

Bachelor of Science in Electrical Engineering Requirements

(197 credits required for the degree (http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofscienceinelectricalengineering/))

This program requires a minimum of 197 credits. Students not in the BSEE/MBA combined program select a specialization from communication systems and digital signal processing; robotics, electronics, photonics and microsystems; or power and energy; or, under special circumstances, an individualized specialization may also be approved. Faculty mainly associated with electrical engineering pursue research in the areas of communication systems and networks, digital signal processing, optical communication devices and systems, photonics, robotics and controls, and autonomous systems.

Requirements

197 credits are required for the degree including 48 credits of mathematics and basic science and 75 - 83 credits of engineering topics.

Code	Title	Credits
ENCE 2101	Digital Design	3
ENCE 3210	Microprocessor Systems I	4
ENEE 2012	Circuits I and Laboratory	4
ENCE 3231	Embedded Systems Programming	4
ENEE 2022	Circuits II	4
ENEE 2211	Electronics	4
ENEE 2223	Advanced Electronics	4
ENEE 2611	Engineering Electromagnetics	4
ENEE 3011	Physical Electronics	4
ENEE 3111	Signals & Systems	4
ENEE 3130	Principles of Communication Systems	3
ENGR 1511	Engineering Connections	1
ENGR 1572	Applied MATLAB Programming	3
ENGR 1611	Introduction to Engineering Design	4
ENGR 1622	Introduction to Mechatronic Systems I	4
ENGR 1632	Introduction to Mechatronic Systems II	4
ENGR 2610	Engineering Integration I	3
ENGR 2620	Engineering Integration II	3
ENGR 2950	Engineering Assessment I	0
ENGR 2951	Engineering Assessment II	0
ENGR 3100	Instrumentation and Data Acquisition	4
ENGR 3313	Engineering Design Project I	2
ENGR 3323	Engineering Design Project II	3
ENGR 3333	Engineering Design Project III	3
ENGR 3510	Renewable and Efficient Power and Energy Systems	4
ENGR 3530	Introduction to Power and Energy Conversion Systems	3
ENGR 3721	Controls	3
ENGR 3611	Engineering Mathematics	3
ENGR 3650	Probability and Statistics for Engineers	4
ENGR 3722	Control Systems Laboratory	1
ENGR 3735	Linear Systems	4
ENME 2510	Statics with Lab	4
ENME 2520	Dynamics I with Lab	4
ENME 2541	Mechanics of Materials	3
ENGR 2910	Engineering Economics and Ethics	3
Technical Electives		12

Notes

Technical electives are used to complete specializations for the degree. Only technical courses may be used, and these must carry upper-division credit. Prior approval by the advisor is required.

Additional Requirements

Chemistry

Code	Title	Credits
CHEM 1010	General Chemistry I	3
CHEM 1240	General Chemistry I Laboratory	1

Computer Science

Code	Title	Credits
COMP 1351	Introduction to Programming I	3

Mathematics

Code	Title	Credits
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
MATH 1953	Calculus III	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4

Physics

Code	Title	Credits
PHYS 1211	University Physics I	5
PHYS 1212	University Physics II	5
PHYS 1214	University Physics III for Engineers	4

Notes

Areas of Specialization

All Bachelor of Science in Electrical Engineering students are required to choose an area of specialization. The area of specialization can be fulfilled through the students choice of technical electives. For specific courses in the specialization areas, please see Degree Program Plan.

- **Communications Systems and Digital Signal Processing**
- **Robotics**
- **Electronics, Photonics, and Microsystems**
- **Power and Energy**
- **Individualized Option**

Nine credits of upper-division technical courses selected with advisor's approval.

Electrical Engineering with a Concentration in Mechatronic Systems Engineering

This degree program requires a minimum or 195 credits. Students not in the BSEE with a concentration in mechatronic systems engineering/MBA combined program select a specialization from mechanical systems, computer control and systems; or, under special circumstances, an individualized specialization may also be approved. Faculty associated with mechatronic systems engineering pursue research in the areas of robotics and controls and unmanned aerial systems.

Requirements for the Concentration

(195 credits required for the degree (http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofscienceinelectricalengineering/))

195 credits are required for the degree including 48 credits of mathematics and basic science and 75 - 83 credits of engineering topics.

Code	Title	Credits
ENCE 2101	Digital Design	3
ENCE 3210	Microprocessor Systems I	4
ENEE 2012	Circuits I and Laboratory	4
ENCE 3231	Embedded Systems Programming	4
ENEE 2022	Circuits II	4
ENEE 2211	Electronics	4
ENEE 2223	Advanced Electronics	4
ENEE 2611	Engineering Electromagnetics	4
ENEE 3111	Signals & Systems	4
ENGR 1511	Engineering Connections	1
ENGR 1572	Applied MATLAB Programming	3
ENGR 1611	Introduction to Engineering Design	4
ENGR 1622	Introduction to Mechatronic Systems I	4
ENGR 1632	Introduction to Mechatronic Systems II	4
ENGR 2610	Engineering Integration I	3
ENGR 2620	Engineering Integration II	3
ENGR 2950	Engineering Assessment I	0
ENGR 2951	Engineering Assessment II	0
ENGR 3100	Instrumentation and Data Acquisition	4
ENGR 3313	Engineering Design Project I	2
ENGR 3323	Engineering Design Project II	3
ENGR 3333	Engineering Design Project III	3
ENGR 3530	Introduction to Power and Energy Conversion Systems	3
ENGR 3611	Engineering Mathematics	3
ENGR 3650	Probability and Statistics for Engineers	4
ENGR 3721	Controls	3
ENGR 3722	Control Systems Laboratory	1
ENGR 3730	Robotics	3
ENGR 3731	Robotics Lab	1
ENGR 3735	Linear Systems	4
ENME 2510	Statics with Lab	4
ENME 2520	Dynamics I with Lab	4
ENME 2541	Mechanics of Materials	3
ENMT 3220	Mechatronics II - Real-Time Systems	4
ENGR 2910	Engineering Economics and Ethics	3
Technical Electives		10

Notes

Technical electives are used to complete specializations for the degree. Only technical courses may be used, and these must carry upper-division credit. Prior approval by the advisor is required.

Additional Requirements

Chemistry

Code	Title	Credits
CHEM 1010	General Chemistry I	3
CHEM 1240	General Chemistry I Laboratory	1

Computer Science

Code	Title	Credits
COMP 1351	Introduction to Programming I	3

Mathematics

Code	Title	Credits
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
MATH 1953	Calculus III	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4

Physics

Code	Title	Credits
PHYS 1211	University Physics I	5
PHYS 1212	University Physics II	5
PHYS 1214	University Physics III for Engineers	4

Notes

BSEE-MSE Specialization

All EE-MSE students are required to choose an area of specialization. The area of specialization can be fulfilled through the students choice of technical electives. For specific courses in the specialization areas, please see Degree Program Plan.

- **Mechanical Systems**
- **Computer Systems**
- **Individualized Option**

Nine quarter hours of upper division technical courses selected with advisor's approval.

Minor Requirements for Electrical Engineering

20 credits including:

Code	Title	Credits
ENEE 2012	Circuits I and Laboratory	4
ENEE 2022	Circuits II	4
ENEE 2211	Electronics	4
ENEE 3111	Signals & Systems	4
Electives		
ENEE courses at the 2000-level or above		4
Total Credits		**20**

Computer Engineering

Bachelor of Science in Computer Engineering

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
FSEM 1111	4	ENGR 1622	4	ENGR 1632	4
CHEM 1010	3	MATH 1952	4	MATH 1953	4
CHEM 1240	1	PHYS 1211	5	PHYS 1212	5
ENGR 1511	1	WRIT 1122	4	WRIT 1133	4
ENGR 1611	4				
MATH 1951	4				
	17		**17**		**17**
Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COMP 1351	3	ENEE 2012	4	ENEE 2022	4
ENCE 2101	3	ENGR 1572	3	ENGR 2950	0
ENME 2510	4	ENME 2541	3	ENGR 3100	4

PHYS 1214	4	MATH 2070	4	MATH 2080	4
University Common Curriculum (UCC)	4	UCC	4	COMP 1352	3
	18		18		15
Third Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
ENCE 3100	4	ENGR 2610	3	ENGR 2620	3
ENEE 2211	4	ENCE 3210	4	ENCE 3231	4
ENEE 3111	4	ENGR 3650	4	ENCE 3260	3
COMP 1353	3	MATH/SCI	4	COMP 2361	4
	15		15		14
Fourth Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COMP 2300	4	ENGR 3323	3	ENGR 3333	3
COMP 2362	4	Technical Elective	4	ENGR 2951	0
ENCE 3501	3	ASEM 2XXX (Advanced Seminar)	4	ENGR 2910	3
ENGR 3313	2	UCC	4	Technical Elective	4
Technical Elective	4			UCC	4
	17		15		14
Total Credits: 192					

Notes

Common Curriculum - These may be taken in any order. They must have 2 courses with attributes of analytical inquiry: society and 2 courses attributes of scientific inquiry: society.

ASEM 2XXX - Advanced Seminar Engineering students are required to take a writing-intensive advanced seminar. Junior standing is also required.

Technical Elective. Technical electives are used to complete specializations for the degree. Only technical courses may be used, and these must carry upper-division credit. Prior approval by the advisor is required.

Math/Sci. One (1) math or science course from the approved list (4 credits). Note that without prior advisor approval only one approved math or science course may be taken instead of a UCC course in the first two years.

Total credits may vary based on technical elective options.

Approved Math/Sci Courses (subject to participating department course offerings):

Biology

BIOL 1010 Physiological Systems w/ BIOL 1020 Physiological Systems Lab;BIOL 1011 Evolution, Heredity and Biodiversity w/ BIOL 1021 Evolution, Heredity and Biodiversity Lab;;BIOL 2090 Biostatistics; BIOL 2120 Cell Structure and Function w/ BIOL 2121 Cell Structure & Function Lab; BIOL 3250 Human Physiology

Chemistry

CHEM 1020 General Chemistry II w/ CHEM 1250 General Chemistry II Laboratory; CHEM 2131 Chemistry of the Elements w/ CHEM 2141 Chemistry of the Elements Lab; CHEM 2240 Introduction to Environmental Chemistry; CHEM 2270 Quantitative Chemical Analysis

Math

MATH 2060 Elements of Linear Algebra; MATH 3080 Introduction to Probability; MATH 3090 Mathematical Probability; MATH 3851 Functions Complex Variable

Physics

PHYS 2251 Modern Physics I; PHYS 2252 Modern Physics II w/ PHYS 2260 Modern Physics Lab; PHYS 2259 Uncertainty and Error Analysis; PHYS 2300 Physics of the Body; PHYS 2340 Medical Imaging Physics; PHYS 3510 Analytical Mechanics I; PHYS 3711 Optics I

AREAS OF SPECIALIZATION

All Bachelor of Science in Computer Engineering students are required to choose an area of specialization. The area of specialization can be fulfilled through the students choice of technical electives. The students must choose a minimum of 3 courses in one of the areas of specialization.

Communications, DSP, and Networking

Select three courses from the following: [1]		
ENCE 3321	Network Design	4

ENCE 3630	Pattern Recognition	4
ENEE 3130	Principles of Communication Systems	3
ENEE 3141	Digital Communications	3
ENEE 3670	Introduction to Digital Signal Processing	4

Computer Systems Engineering

Select three courses from the following: [1]		
COMP 3501	Introduction to Artificial Intelligence	4
COMP 3801	Introduction Computer Graphics	4
ENCE 3321	Network Design	4
ENCE 3620	Computer Vision	4
ENMT 3220	Mechatronics II - Real-Time Systems	4
COMP 2370	Introduction to Data Structures & Algorithms II	4
ENCE 3631	Machine Learning	4

Robotics, Embedded Systems, and Instrumentation

Select three courses from the following: [1]		
COMP 3501	Introduction to Artificial Intelligence	4
COMP 3801	Introduction Computer Graphics	4
ENCE 3321	Network Design	4
ENCE 3620	Computer Vision	4
ENCE 3630	Pattern Recognition	4
ENGR 3721	Controls	3,4
ENGR 3730	Robotics	3
ENMT 3220	Mechatronics II - Real-Time Systems	4

Individualized Option

Nine credits of upper division technical courses selected with advisor's approval.

[1] Students may also take Special Topics or Independent Study as appropriate for this option

Electrical Engineering

Bachelor or Science in Electrical Engineering Requirements

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
FSEM 1111	4	ENGR 1622	4	ENGR 1632	4
CHEM 1010	3	MATH 1952	4	MATH 1953	4
CHEM 1240	1	PHYS 1211	5	PHYS 1212	5
ENGR 1511	1	WRIT 1122	4	WRIT 1133	4
ENGR 1611	4				
MATH 1951	4				
	17		**17**		**17**
Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COMP 1351	3	ENEE 2012	4	ENEE 2022	4
ENCE 2101	3	ENGR 1572	3	ENGR 2950	0
ENME 2510	4	ENME 2541	3	ENGR 3100	4
University Common Curriculum (UCC)	4	MATH 2070	4	ENME 2520	4
PHYS 1214	4	UCC	4	MATH 2080	4
	18		**18**		**16**
Third Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
ENEE 2211	4	ENCE 3210	4	ENEE 2223	4
ENEE 2611	4	ENEE 3130	3	ENGR 2620	3

ENEE 3111	4	ENGR 2610	3	ENEE 3011	4
ENGR 3530	3	ENGR 3721	3	ENCE 3231	4
ENGR 3611	3	ENGR 3722	1		
		ENGR 3650	4		
	18		18		15
Fourth Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
ENGR 3735	4	ENGR 3510	4	ASEM 2XXX Advanced Seminar	4
ENGR 3313	2	ENGR 3323	3	ENGR 2910	3
UCC	4	UCC	4	ENGR 3333	3
Technical Elective	4	Technical Elective	4	ENGR 2951	0
				Technical Elective	4
	14		15		14

Total Credits: 197

Notes

Common Curriculum - These may be taken in any order. They must have 2 courses with attributes of analytical inquiry: society and 2 courses attributes of scientific inquiry: society.

ASEM 2XXX - Advanced Seminar Engineering students are required to take a writing-intensive advanced seminar. Junior standing is also required.

Technical Elective. Technical electives are used to complete specializations for the degree. Only technical courses may be used, and these must carry upper-division credit. Prior approval by the advisor is required.

AREAS OF SPECIALIZAITON

All Bachelor of Science in Electrical Engineering students are required to choose an area of specialization. The area of specialization can be fulfilled through the students choice of technical electives.

Communications Systems and Digital Signal Processing

Required:		
ENEE 3141	Digital Communications	3
Two of the following: [1]		
ENCE 3321	Network Design	4
ENEE 3620	Optical Fiber Communications	4
ENEE 3670	Introduction to Digital Signal Processing	4

Robotics

Select three courses from the following: [1]		
ENCE 3100	Advanced Digital System Design	4
ENCE 3620	Computer Vision	4
ENGR 3730	Robotics	3
ENME 3545	Mechanisms	4
ENMT 3220	Mechatronics II - Real-Time Systems	4

Electronics, Photonics, and Microsystems

Select three courses from the following: [1]		
ENEE 3030	Optoelectronics	4
ENEE 3035	Photonics	4
ENEE 3620	Optical Fiber Communications	4
ENGR 3520	Introduction to Power Electronics	4
ENGR 3525	Power Electronics and Renewable Energy Laboratory	1

Power and Energy

One of the following: [1]		
ENGR 3525	Power Electronics and Renewable Energy Laboratory	1
ENGR 3535	Electric Power Engineering Laboratory	1
Two of the folloiwing		

ENGR 3520	Introduction to Power Electronics	4
ENGR 3540	Electric Power Systems	4
ENGR 3545	Electric Power Economy	3

Individualized Option

Nine credits of upper-division technical courses selected with advisor's approval.

1 Students may also take Special Topics or Independent Study as approved for this option.

Electrical Engineering with a Concentration in Mechatronic Systems Engineering

Bachelor of Science in Electrical Engineering with a Concentration in Mechatronic Systems Engineering Requirements

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
FSEM 1111	4	ENGR 1622	4	ENGR 1632	4
CHEM 1010	3	MATH 1952	4	MATH 1953	4
CHEM 1240	1	PHYS 1211	5	PHYS 1212	5
ENGR 1511	1	WRIT 1122	4	WRIT 1133	4
ENGR 1611	4				
MATH 1951	4				
	17		**17**		**17**
Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COMP 1351	3	ENEE 2012	4	ENEE 2022	4
ENCE 2101	3	ENGR 1572	3	ENGR 2950	0
ENME 2510	4	ENME 2541	3	ENGR 3100	4
University Common Curriculum (UCC)	4	MATH 2070	4	ENME 2520	4
PHYS 1214	4	UCC	4	MATH 2080	4
	18		**18**		**16**
Third Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
ENEE 2211	4	ENCE 3210	4	ENCE 3231	4
ENEE 3111	4	ENGR 2610	3	ENEE 2223	4
ENGR 3530	3	ENGR 3721	3	ENGR 2620	3
ENGR 3611	3	ENGR 3722	1	ENMT 3220	4
ENEE 2611	4	ENGR 3650	4		
	18		**15**		**15**
Fourth Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
ENGR 3313	2	ENGR 3323	3	ASEM 2XXX Advanced Seminar	4
ENME 2530	3	ENGR 3730	3	ENGR 2910	3
ENGR 3735	4	ENGR 3731	1	ENGR 3333	3
UCC	4	UCC	4	ENGR 2951	0
Technical Elective	4	Technical Elective	3	Technical Elective	3
	17		**14**		**13**

Total Credits: 195

Notes

Common Curriculum - These may be taken in any order. They must have 2 courses with attributes of analytical inquiry: society and 2 courses attributes of scientific inquiry: society.

ASEM 2XXX - Advanced Seminar Engineering students are required to take a writing-intensive advanced seminar. Junior standing is also required.

Technical Elective. Technical electives are used to complete specializations for the degree. Only technical courses may be used, and these must carry upper-division credit. Prior approval by the advisor is required.

AREAS OF SPECIALIZAITON

BSEE-MSE Specialization

All EE-MSE students are required to choose an area of specialization. The area of specialization can be fulfilled through the students choice of technical electives.

Mechanical Systems

Students must choose from 3 of the following: [1]		
ENME 2810	Mechanical Engineering Lab I	3
ENME 3511	Machine Design	3
ENME 3545	Mechanisms	4

Computer Systems

Students must take the following: [1]		
ENCE 3241	Computer Organization and Architecture	3
ENCE 3321	Network Design	4
ENCE 3620	Computer Vision	4

Individualized Option

Nine quarter hours of upper division technical courses selected with advisor's approval.

[1] Students may also take Special Topics or Independent Study as appropriate for this option.

REQUIREMENTS FOR DISTINCTION IN THE MAJOR IN COMPUTER ENGINEERING

- Minimum 3.3 cumulative GPA
- Undergrad research project including Research paper and presentation

REQUIREMENTS FOR DISTINCTION IN THE MAJOR IN ELECTRICAL ENGINEERING

- Minimum 3.3 cumulative GPA
- Undergrad research project including Research paper and presentation

ENCE 2101 Digital Design (3 Credits)
Basic logic concepts. Boolean algebra, truth tables and logic diagrams. Karnaugh maps; programmable devices including ROM's, PLA's and PAL's; data selectors and multiplexors; flip-flops, and memory design of sequential logic circuits. State diagrams, counters, latches and registers; realization of sequential and arbitrary counters; monostable multivibrators. Course includes engineering ethics. Laboratory.

ENCE 3100 Advanced Digital System Design (4 Credits)
Design of logic machines. Finite state machines, gate array designs, ALU and control unit designs, microprogrammed systems. Hardware design of digital circuits using SSI and MSI chips. Introduction to probability and statistics. Application of probability and stochastic processes for cache and paging performance. Laboratories incorporate specification, top-down design, modeling, implementation and testing of actual digital design systems hardware. Simulation of circuits using VHDL before actual hardware implementation. Laboratory. Cross listed with ENCE 4110. Prerequisite: ENCE 2101.

ENCE 3210 Microprocessor Systems I (4 Credits)
Introduction to microprocessors and to the design and operation of computer systems. A study of the microprocessor and its basic support components. Analysis of CPU architectures of modern computers. Assembly language programming. Use of an assembler and other development tools for programming and developing microprocessor-based systems. Laboratory. Cross listed with ENCE 4210. Prerequisite: ENCE 2101.

ENCE 3231 Embedded Systems Programming (4 Credits)
Design, construction and testing of microprocessor systems. Hardware limitations of the single-chip system. Includes micro-controllers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, design methods and testing of embedded systems. Prerequisite: ENCE 3210.

ENCE 3241 Computer Organization and Architecture (3 Credits)
Organization of digital computers; memory, register transfer and datapath; Arithmetic Logic Unit; computer architecture; control unit; I/O systems. Prerequisite: ENCE 2101.

ENCE 3250 HDL Modeling & Synthesis (3 Credits)
Introduction to Hardware Design Language (HDL). Language syntax and synthesis. Applications related to digital system implementation are developed. Project. Prerequisite: ENCE 2101 or instructor's permission.

ENCE 3260 Python for Engineers (3 Credits)
This course introduces python programming to students and gives them programming and mathematical tools that will be useful in different areas of engineering. The course is divided into 2 main parts. Part 1 (Introduction to Python Programming), covers the fundamental concepts of python programming, covering topics from variables and data structures, functions, algorithm complexity, representation of numbers and basics of parallel computing. Part 2 (Introduction to Numerical Methods), gives an overview of a variety of numerical methods that are useful for engineers. The course reviews the basics of linear algebra, discusses the importance of eigenvalues and eigenvectors, regressions and concepts of “discrete Fourier transform” and “fast Fourier transform”.

ENCE 3321 Network Design (4 Credits)
Introduction to network components. Layering of network architecture. Analysis of Local Area Network (LAN) concepts and architecture based on IEEE standards. Design principles including switching and multiplexing techniques, physical link, signal propagation, synchronization, framing and error control. Application of probability and statistics in error detecting and control. Ethernet, Token-ring, FDDI (Fiber Distributed Data Interface), ATM (Asynchronous Transfer Mode), ISDN (Integrated Service Data Networks). Prerequisite: ENEE 3111, ENCE 2101 or permission of instructor.

ENCE 3501 VLSI Design (3 Credits)
Design of Very Large Scale Integration systems. Examination of layout and simulation of digital VLSI circuits using a comprehensive set of CAD tools in a laboratory setting. Studies of layouts of CMOS combinational and sequential circuits using automatic layout generators. Fundamental structures of the layout of registers, adders, decoders, ROM, PLA's, counters, RAM and ALU. Application of statistics and probability to chip performance. CAD tools allow logic verification and timing simulation of the circuits designed. Cross listed with ENCE 4501. Prerequisite: ENCE 3231.

ENCE 3620 Computer Vision (4 Credits)
This course is an introduction to the basic concepts in image processing and computer vision. First, an introduction to low-level image analysis methods, including radiometry and geometric image formation, edge detection, feature detection, and image segmentation are presented. Then, geometric-based image transformations (e.g., image warping and morphing) for image synthesis will be presented in the course. Furthermore, methods for reconstructing three-dimensional scenes including camera calibration, Epipolar geometry, and stereo feature matching are introduced. Other important topics include optical flow, shape from shading, and three-dimensional object recognition. In conclusion, students learn and practice image processing and computer vision techniques that can be used in other areas such as robotics, pattern recognition, and sensor networks. Cross listed with ENCE 4620. Prerequisite: ENEE 3111.

ENCE 3630 Pattern Recognition (4 Credits)
This class provides an introduction to classical pattern recognition. Pattern recognition is the assignment of a physical object or event to one of several prescribed categories. Applications includes automated object recognition in image and videos, face identification, and optical character recognition. Major topics include Bayesian decision theory, Parametric estimation and supervised learning, Linear discriminant functions, Nonparametric methods, Feature extraction for representation and classification, Support Vector Machines. Cross listed with ENCE 4630.

ENCE 3631 Machine Learning (4 Credits)
This class covers topics in machine learning including but not limited to Bayesian decision theory, supervised learning, unsupervised learning and clustering, linear discriminant functions, deep learning, neural networks, linear classification techniques, manifold learning, bag of words, and Support Vector Machines. Cross listed with ENCE-4631.

ENCE 3830 Topics in Computer Engineering (1-5 Credits)
Special topics in computer engineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENCE 3991 Independent Study (1-5 Credits)
Topics in computer engineering investigated under faculty supervision. May be taken more than once. Students must obtain and complete an Independent Study form from the Office of the Registrar. Prerequisite: permission of instructor.

ENCE 3995 Independent Research (1-10 Credits)

ENCE 4110 Modern Digital Systems Design (4 Credits)
This course focuses on the design of digital systems using combinational, sequential, and programmable logic devices and Hardware Description Languages (HDL). Techniques for logic design including asynchronous logic, physical world interfaces to digital systems, and system performance analysis methods are studied. Students also learn HDL-Verilog to program CPLD devices and FPGA systems. Cross listed with ENCE 3100.

ENCE 4210 Microprocessor Systems I (4 Credits)
Introduction to microprocessors and to the design and operation of computer systems. A study of the microprocessor and its basic support components. Analysis of CPU architectures of modern computers. Assembly language programming. Use of an assembler and other development tools for programming and developing microprocessor-based systems. Cross listed with ENCE 3210.

ENCE 4231 Embedded Systems Programming (4 Credits)
Design, construction and testing of microprocessor systems. Hardware limitations of the single-chip system. Includes micro-controllers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, design methods and testing of embedded systems.

ENCE 4250 Advanced Hardware Description Language (HDL) Modeling and Synthesis (4 Credits)
This course covers advanced concepts in Hardware Description and Language (HDl) modeling and Synthesis. It covers topics including but not limited to digital system design, simulation, and synthesis using Verilog HDL and VHDL. The course also covers RTL design, behavioral description, system Verilog, and timing analysis using CAD tools.

ENCE 4501 Advanced VLSI Design (4 Credits)
Advanced techniques in the fabrication and design of VLSI circuits and systems. Modeling of parasitic components. Floor-planning, clock distribution, routing, and low power design. Cross listed with ENCE 3501. Prerequisite: ENCE 3501 or permission of instructor.

ENCE 4620 Advanced Computer Vision (4 Credits)
This course covers advanced concepts in image processing and computer vision including but not limited to image radiometry and geometric formation, edge detection, geometric based transformations (e.g., image warping and morphing), camera calibration, Epipolar geometry, and stereo feature matching. Other advanced topics include optical flow, shape from shading, and three-dimensional object recognition. In conclusion, students learn and practice advanced topics in image processing and computer vision techniques that can be used in other areas such as robotics, pattern recognition, and sensor networks. Cross listed with ENCE 3620. Prerequisite: ENEE 3311.

ENCE 4630 Advanced Pattern Recognition (4 Credits)
This class covers advanced topics in pattern recognition including but not limited to Bayesian decision theory, parametric estimation and supervised learning, linear discriminant functions, nonparametric methods, feature extraction for representation and classification, manifold learning, bag of words, and Support Vector Machines. Cross listed with.

ENCE 4631 Advanced Machine Learning (4 Credits)
This class covers advanced topics in machine learning including but not limited to Bayesian decision theory, supervised learning, unsupervised learning and clustering, linear discriminant functions, deep neural networks, deep learning, linear classification techniques, manifold learning, bag of words, and Support Vector Machines. Cross listed with ENCE 3631.

ENCE 4800 Advanced Topics (CPE) (1-5 Credits)
Various topics in computer engineering as announced. May be taken more than once. Cross-listed with ENCE 3321, ENCE 3620.

ENCE 4991 Independent Study (1-10 Credits)

ENCE 4995 Independent Research (1-18 Credits)

ENCE 5995 Independent Research (1-18 Credits)

ENEE 2012 Circuits I and Laboratory (4 Credits)
An introduction to electrical circuit analysis, design and evaluation. Emphasis on definitions of basic variables, passive circuit components and the ideal operational ampliphier. DC analysis of circuits and d circuit theorems are stressed. AC signals are introduced. Computer analysis software integrated throughout the course. Cross-listed with PHYS 2011. Prerequisites: PHYS 1213 or PHYS 1214, MATH 1953.

ENEE 2022 Circuits II (4 Credits)
AC analysis of linear circuits to include circuit theorems via classical and transform techniques. Emphasis is placed on the Laplace transform, including use of pole-zero and Bode diagrams to analyze and design circuits, including multiple filters (single pole cascade, Butterworth, Chebychev), and step response circuits. Phasor applications to sinusoidal steady state analysis and AC power. Computer analysis software is used as an aid to circuit analysis. Laboratory program practicing time and frequency domain analysis and design techniques on step response and filter problems. Applications to instrumentation and circuits. Prerequisites: ENEE 2012, MATH 2070.

ENEE 2211 Electronics (4 Credits)
Circuit behavior of semiconductor devices. Bipolar and field-effect transistors and their models; basic physical explanation of the functioning of these devices; large- and small-signal analysis of practical circuits; electronic design using both hand and computer methods of calculation and design; biasing methods for amplifier circuits; power supplies and current-source circuits. Design laboratory. Prerequisites: ENEE 2022.

ENEE 2223 Advanced Electronics (4 Credits)
High-frequency transistor models and determination of parameters; Laplace and Fourier analyses of common amplifier circuits; design and analysis of broad-band amplifiers and multistage amplifiers. Basis feedback topologies; Nyquist, root-locus and Bode plot investigations of stability; introduction to amplifier noise; active filter design; sinusoidal oscillators. Prerequisite: ENEE 2211.

ENEE 2611 Engineering Electromagnetics (4 Credits)
The study of Maxwell's equations and their experimental and theoretical foundations. Topics include Static electromagnetic fields, time-varying electromagnetic fields, wave propagation, transmission lines, and antennas. Prerequisites: PHYS 1213 or PHYS 1214. Corequisite: ENGR 3611 or ENGR 3621.

ENEE 3011 Physical Electronics (4 Credits)
The basic physical concepts of electronics, electrons and holes in semiconductors, transport and optical processes. Concentration on device concepts, including material synthesis and device processing, P-N junction diodes, junctions with other materials, bipolar transistors, field effect transistors (JFET, MESFET, MOSFET) and optoelectronic effect transistors (JFET, MESFET, MOSFET) and optoelectronic devices (lasers, detectors). Prerequisites: CHEM 1010 or CHEM 1610, PHYS 1213 or PHYS 1214 or permission of instructor.

ENEE 3030 Optoelectronics (4 Credits)
The active and passive optical elements. Includes principles of light, optical sources (LED, LASER, Fiber Laser), optical fibers, photodetectors (APD, PIN, MSM) and practical optical transmitter and receivers. Laboratory. Cross listed with ENEE 4030. Prerequisite: ENEE 3011 or ENEE 2211 or permission of instructor.

ENEE 3035 Photonics (4 Credits)
Theory and techniques for the application of the optical electromagnetic spectrum from infrared to ultraviolet to engineering problems in communications, instrumentation and measurement. May include lasers, optical signal processing, holography, nonlinear optics, optical fiber communications, optical behavior of semiconductors, and similar topics in modern optics, depending on the interests and requirements of the students. Cross-listed with ENEE 4800. Prerequisite: ENEE 2611 or instructor's permission.

ENEE 3111 Signals & Systems (4 Credits)
Introduces continuous time and discrete time linear system analysis, Fourier series, Fourier transforms and Laplace transforms. Specific engineering tools for discrete time linear system analysis include discrete time convolution, Z-transform techniques, discrete Fourier transform and fast Fourier transform (DFT/FFT), and the design and analysis of analog and digital filters for real-world signal processing applications. Prerequisites: ENEE 2012, MATH 2070.

ENEE 3130 Principles of Communication Systems (3 Credits)
Introduction to the theory and analysis of communication systems. Emphasis on analog systems; application of probability and statistics, modulations and demodulations; noise and signal-to-noise ratio analysis; the measure of information, channel capacity, coding and design factors. Prerequisites: ENEE 3111, ENGR 3611 or permission of instructor.

ENEE 3141 Digital Communications (3 Credits)
Introductory course on modern digital communication systems. The basic communication system theory, probability and random processes, baseband digital data transmission, coherent and non-coherent digital modulation techniques and analysis of bit error probability. Bandwidth efficiency and transmission of digital data through band-limited channels. Prerequisites: ENEE 3111, ENGR 3611 or permission of instructor.

ENEE 3620 Optical Fiber Communications (4 Credits)
A comprehensive treatment of the theory and behavior of basic constituents, such as optical fibers, light sources, photodetectors, connecting and coupling devices, and optical amplifiers. The basic design principles of digital and analog optical fiber transmission links. The operating principles of wavelength-division multiplexing (WDM) and the components needed for its realization. Descriptions of the architectures and performance characteristics of complex optical networks for connecting users with a wide range of transmission needs (SONET/SDH). Discussions of advanced optical communication techniques, such as soliton transmission, optical code-division multiplexing (optical CDMA) and ultra-fast optical time-division multiplexing (OTDM). Laboratory. Cross listed with ENEE 4620. Prerequisite: ENEE 3030 or permission of instructor.

ENEE 3641 Introduction to Electromagnetic Compatibility (4 Credits)
The study of the design of electronic systems so that they operate compatibly with other electronic systems and also comply with various governmental regulations on radiated and conducted emissions. Topics may include Electromagnetic Compatibility (EMC) requirements for electronic systems; non-ideal behavior of components; radiated emissions and susceptibility; conducted emissions and susceptibility; shielding and system design for EMC. Cross listed with ENEE 4640. Prerequisites: ENEE 3111, ENEE 2611 and ENEE 2223.

ENEE 3670 Introduction to Digital Signal Processing (4 Credits)
Introduction to the theory and applications of Digital Signal Processing. Special attention is paid to the fast Fourier transform and convolution and to the design and implementation of both FIR and IIR digital filters. Prerequisite: ENEE 3111.

ENEE 3810 Topics Electrical Engineering (1-5 Credits)
Various topics in electrical engineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENEE 3991 Independent Study (1-5 Credits)
Topics in electrical engineering investigated under faculty supervision. May be taken more than once. Students must obtain and complete an Independent Study form from the Office of the Registrar. Prerequisite: permission of instructor.

ENEE 4030 Optoelectronics (4 Credits)
Optical fibers: structures, waveguiding, and fabrication; attenuation and dispersion; optical sources (LED, LASER, Fiber laser); power launching and coupling; photodetectors (APD, PIN, MSM); and practical optical transmitter and receivers. Cross listed with ENEE 3030.

ENEE 4141 Digital Communications (4 Credits)
Introductory course on modern digital communication systems. The basic communication system theory, probability and random processes, baseband digital data transmission, coherent and non-coherent digital modulation techniques and analysis of bit error probability. Bandwidth efficiency and transmission of digital data through band-limited channels.

ENEE 4620 Adv Optical Fiber Comm (4 Credits)
A comprehensive treatment of the theory and behavior of basic constituents, such as optical fibers, light sources, photodetectors, connecting and coupling devices, and optical amplifiers. The basic design principles of digital and analog optical fiber transmission links. The operating principles of wavelength-division multiplexing (WDM) and the components needed for its realization. Descriptions of the architectures and performance characteristics of complex optical networks for connecting users who have a wide range of transmission needs (SONET/SDH). Discussions of advanced optical communication techniques, such as soliton transmission, optical code-division multiplexing (optical CDMA), and ultra-fast optical time division multiplexing (OTDM). Advanced Project. Cross listed with ENEE 3620. Prerequisite: instructor permission.

ENEE 4630 Optical Networking (4 Credits)
This course provides a technical overview of optical networking. It gives students a solid understanding of optical networking field principles and practice. Underlying principles are reviewed along with common optical solutions and practices. It explains and provides practical tips on how to design and implement Networks. Examples are used to demonstrate key concepts of ATM, SONET/SDH and DWDM implementation. Prerequisite: ENEE 3011 or instructor approval.

ENEE 4640 Electromagnetic Compatibility (4 Credits)
The study of the design of electronic systems so that they operate compatibly with other electronic systems and also comply with various governmental regulations on radiated and conducted emissions. Topics may include: Electromagnetic Compatibility (EMC) requirements for electronic systems; non-ideal behavior of components; radiated emissions and susceptibility; conducted emissions and susceptibility; shielding and system design for EMC. Final Project. Cross listed with ENEE 3641.

ENEE 4800 Advanced Topics (EE) (1-5 Credits)
Various advanced topics in electrical engineering as announced. May be taken more than once. Cross-listed with ENEE 3035.

ENEE 4950 ECE Graduate Assessment (0 Credits)
This class does not meet. All graduate (MS and PhD) ECE students will enroll in this class during their last quarter. All required assessment materials will be uploaded online in Canvas Assignments to meet the course requirements. Students will receive Canvas course announcements and or emails from the instructor notifying the students of what are required to be uploaded. The purpose is to collect data for the assessment and continuous improvement of the graduate programs.

ENEE 4991 Independent Study (1-10 Credits)

ENEE 4995 Independent Research (1-16 Credits)

ENEE 6991 Ph.D Independent Study (1-10 Credits)

ENEE 6995 Independent Research (1-16 Credits)

ENGR 1010 Electronics for the Arts 1 - Analog (4 Credits)
Introduction to analog electronics, culminating in construction of an analog sound synthesizer. Students are required to complete simple projects with circuits while learning the basics of analog synthesizers. Introduction to circuit simulation software (e.g. Falstad or Multisim), learn how to use oscilloscopes and multimeters, design and solder PCB boards are among other topics covered in this course.

ENGR 1011 Electronics for the Arts 2 - Digital (4 Credits)
Introduction to digital electronics and coding for Arduino style microprocessors, culminating in design and construction of a hybrid analog/digital sound synthesizer or other device. Students are required to complete simple projects with Arduino while learning the basics of digital synthesizers. Introduction to programming, reinforce the use of oscilloscopes and multimeters, design and solder PCB boards are among other topics covered in this course.

ENGR 1012 Electronics for the Arts 3 - Digital (4 Credits)
Individual or team-based development of more complex devices or systems, potential for product development. Students are required to complete complex projects that involve combining analog and digital synthesizers with the external world (sensors and/or actuators). Introduction to python programming and incorporation of artificial intelligence (AI) into synthesizers are among other topics covered in this course.

ENGR 1511 Engineering Connections (1 Credit)
This course is designed to help engineering students bridge the gap from high school to a college environment in a very challenging major. Topics and activities may include academic success strategies; interviewing engineering alumni; the ethics of the profession; visits to industry sites; seminars by industry and academic experts; establishing the relationships between math, science, and engineering courses with design projects; critical and creative thinking activities; tours of the research labs of the engineering professors; disseminating information on the dual degree programs, the MBA programs, the honor code, and engineering program structures; and readings from and discussions about articles from professional publications. Membership in an engineering professional society is encouraged.

ENGR 1572 Applied MATLAB Programming (3 Credits)
The MATLAB programming environment is used to introduce engineering applications programming. It includes high performance numerical computation and visualization. Programming topics include an overview of an interactive programming environment, generation of m-files, variables and data types, arithmetic operators, mathematical functions, symbolic mathematics, graphic generation, use of programs in application specific toolboxes, embedding and calling C programs in m-files, file input/output, and commenting. Programming is oriented toward engineering problem solving. Prerequisites: COMP 1571 or COMP 1671 or COMP 1351, and MATH 1952.

ENGR 1611 Introduction to Engineering Design (4 Credits)
Introduction to concepts and practice in computer, electrical and mechanical engineering including engineering ethics. Engineering problem-solving as it applies to engineering analysis, synthesis and design. Students practice structured teamwork and program management skills in the context of projects. Emphasis on computer tools with immediate application to engineering practice.

ENGR 1622 Introduction to Mechatronic Systems I with MultiSim and MathCAD (4 Credits)
Introduction to elementary concepts and practices in mechatronic systems engineering, in particular electrical engineering concepts including current and voltage and basic electrical circuit analysis, interfacing electrical circuits with mechanical systems, and assembly and testing of mechatronics subsystems. Students are required to complete simple projects including mechanical and electrical components during which they practice teamwork while gaining skills in electrical and mechatronic systems troubleshooting. Introduction to Multiscan circuit analysis software and Mathcad are among other topics covered in this course.

ENGR 1632 Introduction to Mechatronic Systems II (4 Credits)
Study of fundamentals of computer-based systems and electromechanical systems controlled by microprocessors or microcontrollers. Introduction to digital logic and electronics. Introduction to LabView and use of LabView to build and evaluate circuits and simple electromechanical systems. Use of logic circuits to build analog to digital converters. Program microcontrollers. Study of autonomous vehicles as mechatronic systems and the ability to control them (small cars, robots, helicopters, quadrotors, etc.). Course requirements include a report with detailed analysis of the vehicle control system, flow charts, and program documentation.

ENGR 1700 Machine Shop Practice (1 Credit)
Introduction to concepts and practice in basic machine tool work (i.e. mill, lathe, welding etc.). The course provides the necessary information for majors and non-majors to gain access to the DU Engineering Machine Shop. Class size is limited to 5 students per quarter. Enrollment priority will be given to engineering majors.

ENGR 1911 Introduction to CAD (2 Credits)
This course is intended for transfer students who have had an introduction to engineering, but who need to learn certain techniques and software typically dealt with in ENGR 1611 including engineering ethics. Instructor Permission Required.

ENGR 1921 Introduction in Engineering II (1 Credit)
This course is intended mainly for transfer students who have had an introduction to engineering with topics similar to those in ENGR 1622, Introduction to Mechatronic Systems I, but who need to learn certain techniques and software (Mathcad and Multisim) typically dealt with in ENGR 1622. Prerequisite: Permission of the instructor.

ENGR 1931 Introduction to Engineering III (1 Credit)
This course is intended mainly for transfer students who have had an introduction to engineering with topics similar to those in ENGR 1632, Introduction to Mechatronic Systems II, but who need to learn certain techniques and software (LabView) typically dealt with in ENGR 1632. Prerequisite: Permission of the instructor.

ENGR 2610 Engineering Integration I (3 Credits)
Interdisciplinary course combining topics from computer, electrical and mechanical engineering including engineering ethics, with emphasis on laboratory experience and the design, analysis and testing of interdisciplinary systems. Manufacture of mechanical systems and/or circuit boards. Team project work on interdisciplinary "design-and-build" projects. Prerequisites: Junior standing in the appropriate engineering discipline and ENME 3511 for MME majors or ENCE 3210 and ENEE 2211 for ECE majors (the latter three can be taken concurrently).

ENGR 2620 Engineering Integration II (3 Credits)
Interdisciplinary course combining topics from computer, electrical and mechanical engineering including engineering ethics, with emphasis on laboratory experience and the design, analysis and testing of interdisciplinary systems. Manufacture of mechanical systems and/or circuit boards. Team project work on interdisciplinary "design-and-build" projects. Prerequisite: ENGR 2610.

ENGR 2905 Engineering Cooperative Education (0-12 Credits)
For students on full-time cooperative educational employment. This course may be taken up to four times. Any and all credits will not count toward your degree and you will receive a grade of NC (no credit) for all enrollments. You will choose between a residential and non-residential section.

ENGR 2910 Engineering Economics and Ethics (3 Credits)
This course focuses on the practical applications of economics to engineering focusing on the requirements for both the FE and PE exams. It explains concepts in accounting and finance and applies them to both engineering and personal situations. Topics that are discussed include: economic decision making, interest, inflation, depreciation, income taxes, and rate of return. In addition, the engineer's role in society, including global, economic, environmental, societal, and ethical issues will be discussed.

ENGR 2950 Engineering Assessment I (0 Credits)
Examination covering basic mathematics, science and sophomore-level engineering topics. Co-Requisite: MATH 2080; Prerequisite: ENME 2541 AND ENCE 2101 AND ENEE 2012 AND ENGR 1572.

ENGR 2951 Engineering Assessment II (0 Credits)
Students perform a lifelong learning experience and assessment-related tasks, e.g. a survey and exit interview. The course also includes career and professional development, as well as information on the Fundamentals of Engineering (FE) exam. Engineering students are encouraged, but not required to complete the FE exam. This course should be taken in the last year of attendance. Prerequisites: ENGR 3323.

ENGR 3100 Instrumentation and Data Acquisition (4 Credits)
This course examines different instrumentation techniques and describes how different measurement instruments work. Measurement devices include length, speed, acceleration, force, torque, pressure, sound, flow, temperature, and advanced systems. This course also examines the acquisition, processing, transmission and manipulation of data. Cross listed with ENGR 4100. Prerequisites: PHYS 1213 or PHYS 1214.

ENGR 3200 Introduction to Nanotechnology (4 Credits)
In this highly interdisciplinary series of lectures spanning across engineering, physics, chemistry and Biology, an introduction to the subject of nanotechnology is provided. The most important recent accomplishments so far in the application of nanotechnology in several disciplines are discussed. Then a brief overview of the most important instrumentation systems used by nanotechnologists is provided. The nature of nanoparticles, nanoparticle composites, carbon nanostructures, including carbon nanotubes and their composites is subsequently discussed. The course also deals with nanopolymers, nanobiological systems, and nanoelectronic materials and devices. The issues of modeling of nanomaterials and nanostructures are also covered in this class. Multiscale modeling based on finite element simulations, Monte Carlo methods, molecular dynamics and quantum mechanics calculations is briefly addressed. Most importantly, students should obtain appreciation of developments in nanotechnology outside their present area of expertise. Cross listed with ENGR 4200. Prerequisite: ENME 2410.

ENGR 3220 Introduction to Micro-Electro-Mechanical-Systems and Microsystems (4 Credits)
This course introduces students to the multi-disciplinary field of Micro-Electro-Mechanical-Systems (MEMS) technology. MEMS and Microsystem technology is the integration of micro-scale electro-mechanical elements, sensors, actuators, and electronics on a common substrate or platform through semiconductor microfabrication technologies. The course gives a brief overview of the involved physical phenomena, electromechanical transduction mechanisms, design principles, as well as fabrication and manufacturing technologies. Cross listed with ENGR 4220.

ENGR 3313 Engineering Design Project I (2 Credits)
Planning, development and execution of an engineering design project. The project may be interdisciplinary, involving aspects of computer, electrical and mechanical engineering. Projects have economic, ethical, social and other constraints, as appropriate. Design activities include 1) preparation and presentation of proposals in response to requests-for-proposals from "customers," including problem description, quantitative and qualitative criteria for success, alternate designs and project plans; 2) generation and analysis of alternate designs, and choice of best design; 3) formulation of test procedures to demonstrate that the design chosen meets the criteria for success, and testing of the completed project where feasible; 4) reporting on the design and testing. Prerequisite: ENGR 2620 and ((ENME 3511 and ENME 2671) or (ENCE 3231)) and senior standing in engineering.

ENGR 3323 Engineering Design Project II (3 Credits)
Planning, development and execution of an engineering design project. The project may be interdisciplinary, involving aspects of computer, electrical and mechanical engineering. Projects have economic, ethical, social and other constraints, as appropriate. Design activities include 1) preparation and presentation of proposals in response to requests-for-proposals from "customers," including problem description, quantitative and qualitative criteria for success, alternate designs and project plans; 2) generation and analysis of alternate designs, and choice of best design; 3) formulation of test procedures to demonstrate that the design chosen meets the criteria for success, and testing of the completed project where feasible; 4) reporting on the design and testing. Prerequisite ENGR 3313.

ENGR 3333 Engineering Design Project III (3 Credits)
Planning, development and execution of an engineering design project. The project may be interdisciplinary, involving aspects of computer, electrical and mechanical engineering. Projects have economic, ethical, social and other constraints, as appropriate. Design activities include: 1) preparation and presentation of proposals in response to requests-for-proposals from "customers," including problem description, quantitative and qualitative criteria for success, alternate designs and project plans; 2) generation and analysis of alternate designs, and choice of best design; 3) formulation of test procedures to demonstrate that the design chosen meets the criteria for success, and testing of the completed project where feasible; 4) reporting on the design and testing. Prerequisite ENGR 3323.

ENGR 3340 Product Development and Market Feasibility (4 Credits)
In this course, students gain knowledge of designing products for market success by developing a product and optimizing its design for specific mass manufacturing technologies. Students gain experience through the design development process including market feasibility research, human-centered design, brainstorming and ideating new concepts, refinement through design iteration, and constructing alpha and beta prototypes that are designed with mass manufacturing considerations. Projects are based upon real world new product development principles. Students learn and practice the fundamentals of design thinking, design process, and entrepreneurship.

ENGR 3510 Renewable and Efficient Power and Energy Systems (4 Credits)
This course introduces the current and future sustainable electrical power systems. Fundamentals of renewable energy sources and storage systems are discussed. Interfaces of the new sources to the utility grid are covered. Prerequisite: ENEE 2012.

ENGR 3520 Introduction to Power Electronics (4 Credits)
This covers fundamentals of power electronics. We discuss various switching converters topologies. Basic knowledge of Efficiency and small-signal modeling for the DC-DC switching converters is covered. Furthermore, magnetic and filter design are introduced. Prerequisites: ENEE 2211 and ENGR 3722.

ENGR 3525 Power Electronics and Renewable Energy Laboratory (1 Credit)
In this course the fundamentals of switching converters and power electronics in a real laboratory set-up are covered. The course incorporates hardware design, analysis, and simulation of various switching converters as a power processing element for different energy sources. The energy sources are power utility, batteries, and solar panels. Prerequisite: ENGR 3520.

ENGR 3530 Introduction to Power and Energy Conversion Systems (3 Credits)
Basic concepts of AC systems, single-phase and three-phase networks, electric power generation, transformers, transmission lines, and electric machinery. Cross listed with ENGR 4530. Prerequisite: ENEE 2022.

ENGR 3535 Electric Power Engineering Laboratory (1 Credit)
In this laboratory, the magnetic circuits, single phase transformers, power quality and harmonics synchronous machines, Induction machines and DC machines are studied and tested in a real physical setup. Prerequisite: ENGR 3530.

ENGR 3540 Electric Power Systems (4 Credits)
This course covers methods of calculation of a comprehensive idea on the various aspects of power system problems and algorithms for solving these problems. Prerequisite: ENGR 3530.

ENGR 3545 Electric Power Economy (3 Credits)
This course covers economy aspects of electric power industry and the implications for power and energy engineering in the market environment. Cross listed with ENGR 4545. Prerequisite: ENGR 3530.

ENGR 3590 Power System Protection (3 Credits)
This course covers methods of calculation of fault currents under different types of faults; circuit breakers, current transformers, potential transformers; basic principles of various types of relays; applications of relays in the protection of generator, transformer, line, and bus, etc. Prerequisite: ENEE 2022, ENGR 3530 or equivalent. 3.0 hours. Cross listed with ENGR 4590.

ENGR 3611 Engineering Mathematics (3 Credits)
Applied mathematics for engineers. Generalized Fourier analysis, complex variables, vector calculus, introduction to partial differential equations, and linear algebra. Prerequisites: MATH 2070, MATH 2080.

ENGR 3620 Advanced Engineering Mathematics (4 Credits)
Applied mathematics for engineers. Systems and series solutions of ordinary differential equations, Fourier analysis, partial differential equations, linear algebra, vector calculus, special functions, unconstrained and combinatorial optimization, and applied probability and statistics. Prerequisites: MATH 2070 and MATH 2080 or instructor permission.

ENGR 3621 Advanced Engineering Mathematics (4 Credits)
Applied mathematics for engineers. Topics include vector spaces, normed vector spaces, inner product spaces, linear transformations, finite-dimensional linear transformations, linear operators, finite-dimensional linear operators, linear differential systems, linear difference systems, orthogonal transformations, amplitude estimation, fundamentals of real and functional analysis, and introduction to partial differential equations, and applications to engineering systems.

ENGR 3630 Finite Element Methods (4 Credits)
Introduction to the use of finite element methods in one or two dimensions with applications to solid and fluid mechanics, heat transfer and electromagnetic fields; projects in one or more of the above areas. Prerequisites: ENME 2541 AND ENGR 1572.

ENGR 3650 Probability and Statistics for Engineers (4 Credits)
This course covers quantitative analysis of uncertainty and decision analysis in engineering. It covers the fundamentals of sample space, probability, random variables (discrete and continuous), joint and marginal distributions, random sampling and point estimation of parameters. It also covers statistical intervals, hypotheses testing and simple linear regression. The course includes applications appropriate to the discipline. Prerequisite: MATH 1953.

ENGR 3721 Controls (3,4 Credits)
Modeling, analysis and design of linear feedback control systems using Laplace transform methods. Techniques and methods used in linear mathematical models of mechanical, electrical, thermal and fluid systems are covered. Feedback control system models, design methods and performance criteria in both time and frequency domains. A linear feedback control system design project is required. Prerequisites: ENEE 2022, ENGR 3611 or permission of instructor.

ENGR 3722 Control Systems Laboratory (1 Credit)
This laboratory course serves as supplement to ENGR 3721. It aims at providing "hands on" experience to students. It includes experiments on inverted pendulum, gyroscopes, motor control, feedback controller design, time-domain and frequency domain. Corequisite: ENGR 3721.

ENGR 3723 Digital Control (4 Credits)
The course focuses on modeling, analysis, and design of digital control systems. Topics include: z-Transform and difference equations; sampling and aliasing; Zero-Order Hold (ZOH); A/D and D/A conversions; pulse transfer function representation; time and frequency domain representations; input/output analysis; analysis of sample data systems; stability; design of discrete-time controllers; introduction to state-space representation. Cross listed with ENGR 4723. Prerequisites: ENGR 3721 and ENGR 3722.

ENGR 3730 Robotics (3 Credits)
Introduction to the analysis, design, modeling and application of robotic manipulators. Review of the mathematical preliminaries required to support robot theory. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning, and kinetics. Cross listed with ENGR 4730. Prerequisites: ENME 2520 and MATH 2060 or MATH 2200 or permission of instructor.

ENGR 3731 Robotics Lab (1 Credit)
Laboratory that complements the analysis, design, modeling and application of robotic manipulators. Implementation of the mathematical structures required to support robot operation. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning and kinetics. Applications include programming and task planning of a manufacturing robot manipulator. Corequisite: ENGR 3730 or permission of instructor.

ENGR 3735 Linear Systems (4 Credits)
This course focuses on linear system theory in time domain. It emphasizes linear and matrix algebra, numerical matrix algebra and computational issues in solving systems of linear algebraic equations, singular value decomposition, eigenvalue-eigenvector and least-squares problems, linear spaces and linear operator theory. It studies modeling and linearization of multi-input/multi-output dynamic physical systems, state-variable and transfer function matrices, analytical and numerical solutions of systems of differential and difference equations, structural properties of linear dynamic physical systems, including controllability, observability and stability. It covers canonical realizations, linear state-variable feedback controller and asymptotic observer design, and the Kalman filter. Cross listed with ENGR 4735. Prerequisites: ENGR 3611, ENGR 3721, and ENGR 3722, or permission of the instructor.

ENGR 3800 Topics (ENGR) (1-4 Credits)
Special topics in engineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENGR 3900 Engineering Internship (0-4 Credits)
Students in engineering may receive elective credit for engineering work performed for engineering employers with the approval of the chair or associate chair of the department. At the end of the term, a student report on the work is required, and a recommendation will be required from the employer before a grade is assigned. Junior, senior, or graduate status in engineering is normally required. May not be used to satisfy technical requirements. May be taken more than one for a maximum of 6 quarter hours. Prerequisite: permission of instructor.

ENGR 3991 Independent Study (1-5 Credits)
Topics in engineering investigated under faculty supervision. May be taken more than once. Students must obtain and complete an Independent Study form from the Office of the Registrar. Prerequisite: permission of instructor.

ENGR 3995 Independent Research (1-10 Credits)

ENGR 4100 Instrumentation and Data Acquisition (4 Credits)
This course examines different instrumentation techniques and describes how different measurement instruments work. Measurement devices include length, speed, acceleration, force, torque, pressure, sound, flow, temperature, and advanced systems. This course also examines the acquisition, processing, transmission and manipulation of data. Final project or paper. Cross listed with ENGR 3100. Prerequisites: PHYS 1213 OR PHYS 1214.

ENGR 4200 Introduction to Nanotechnology (4 Credits)
The most important recent accomplishments so far in the application of nanotechnology in several disciplines are discussed. Then a brief overview of the most important instrumentation systems used by nanotechnologists is provided. The nature of nanoparticles, nanoparticle composites, carbon nanostructures, including carbon nanotubes and their composites is subsequently discussed. The course also deals with nanopolymers, nanobiological systems, and nanoelectronic materials and devices. The issues of modeling of nanomaterials and nanostructures is also covered. Multiscale modeling based on finite element simulations, Monte Carlo methods, molecular dynamics and quantum mechanics calculations are briefly addressed. Most importantly, students should obtain appreciation of developments in nanotechnology outside their present area of expertise. Cross listed with ENGR 3200.

ENGR 4300 Advanced Numerical Methods (4 Credits)
Fundamental and advanced numerical methods to approximate mathematical problems for engineering applications using modern software such as Matlab. Topics include numerical differentiation and integration, solution to linear and non-linear equations, ordinary and partial differential equations, and initial, boundary, and eigen value problems. Recommended prerequisite: MATH 2070.

ENGR 4350 Reliability (4 Credits)
An overview of reliability-based design. Topics include: fundamentals of statistics, probability distributions, determining distribution parameters, design for six sigma, Monte Carlo simulation, first and second order reliability methods (FORM, SORM). Most Probable Point (MPP) reliability methods, sensitivity factors, probabilistic design. Cross listed with ENGR 3350.

ENGR 4501 Graduate Capstone Design I (3 Credits)
This is a project-centered course. This is the first third of a practical class that plans the engineering design project prior to addressing the design in earnest. This requires teamwork to develop the plan that details the schedule, cost, and who is responsible for which portions of the design effort. In this segment, the engineering teams establish the starting point for the design. This class puts theory into practice with the “shredding” of the RFP, defining a strategy for the team, balancing what has to be done with existing constraints, understanding the “true” problem of the customer, capturing the associated risks, and capturing margins required for the start of any design activity.

ENGR 4502 Graduate Capstone Design II (3 Credits)
This is a project-centered course. This is the second third of a practical class that implements the engineering design process (left side of the vee). This requires teamwork to develop the detailed design, which is a continuation of the accepted proposal. In this segment, the engineering teams add the details to a conceptual design. This class puts theory into practice with requirements development, balancing requirements against the constraints, completing a functional decomposition, developing a CONOPs document, developing a physical architecture, developing a functional architecture, and defining the interfaces through an ICD.

ENGR 4503 Graduate Capstone Design III (3 Credits)
This is a project-centered course. This is the third of a practical class that implements the engineering design process (right side of the vee). This requires teamwork to build, checkout, and test the final product. In this segment, the engineering teams build or procure hardware as a step towards the integration of the system. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. Test data is collected through instrumentation of the final product with a buy-out and certification by the team. Testing may include performance testing and environmental testing as envisioned in the context diagram.

ENGR 4504 Graduate Capstone Design IV (3 Credits)
This is a project-centered course. This is the fourth of a practical class that implements the entire engineering “vee” design process. This requires teamwork to build, checkout, and test the final design product, e.g. hypothetical missile. In this segment, the engineering teams fine-tune the design process which may address advanced topics such as fault management and resilience. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. It may also include addressing the beginning of the program through early management and pre-phase A activities. Test data is collected through instrumentation of the final product with a buy-in and certification by the team. Testing may include performance testing, functional testing, and environmental testing as envisioned in the system process.

ENGR 4530 Intro to Power and Energy (4 Credits)
Basic concepts of AC systems, single-phase and three-phase networks, electromechanical energy conversion, electric power generation, transformers, transmission lines, AC machinery, DC motors, and contemporary topics in power and energy conversion. Cross listed with ENGR 3530.

ENGR 4545 Electric Power Economy (4 Credits)
This course covers economy aspects of electric power industry and the implications for power and energy engineering in the market environment. Cross listed with ENGR 3545.

ENGR 4560 Power Generation Operation and Control (4 Credits)
This course covers economic dispatch of thermal units and methods of solution; transmission system effects; generate with limited energy supply; production cost models; control of generation; interchange of power and energy; power system security; state estimation in power systems; optimal power flow. Prerequisite: ENGR 3530 or ENGR 4530 or permission of instructor.

ENGR 4590 Power System Protection (4 Credits)
This course covers methods of calculation of fault currents under different types of fault; circuit breakers, current transformers, potential transformers; basic principles of various types of relays; applications of relays in the protection of generator, transformer, line, and bus, etc. Prerequisite: ENGR 3530 or ENGR 4530.

ENGR 4620 Optimization (4 Credits)
The development and application of various optimization techniques will be explored with engineering examples. Topics include: analytical and numerical methods, linear and non-linear programming techniques for unconstrained and constrained problems, and advanced optimization techniques, e.g. global optimization. Optimization methods will be developed and evaluated in code and used in a real-world application project.

ENGR 4622 Advanced Optimization (4 Credits)
Optimization is an indispensable tool for many fields of science and engineering and is one of the pillars of data science and machine learning. This course introduces optimization methods that are suitable for large-scale problems arising in data science, machine learning, and other engineering applications. We will discuss the development, computation, and convergence aspects for algorithms including gradient methods, accelerated methods, quasi-Newton methods, stochastic optimization, variance reduction, online optimization, as well as distributed optimization. We will also exploit the efficacy of these methods in concrete data science problems, including learning low-dimensional models, deep learning, and (possible) reinforcement learning. This course together with ENGR 4620 Optimization will provide in-depth introductions to optimization.

ENGR 4680 Fault Diagnosis & Prognostics for System Design (4 Credits)
Reliability engineering is a sub-discipline of systems engineering that emphasizes dependability in the lifecycle management of a product. Reliability, describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability is closely related to availability, which is typically described as the ability of a component or system to function at a specified moment or interval of time. Normally, quality focuses on the prevention of defects during the warranty phase whereas reliability looks at preventing failures during the useful lifetime of the product or system from commissioning to decommissioning. Diagnosis is used, with variations in the use of logic, analytics, and experience, to determine "cause and effect”. In systems engineering, it is typically used to determine the causes of symptoms, mitigations, and solutions. Prognostics is an engineering discipline focused on predicting the time at which a system or a component will no longer perform its intended function. This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the remaining useful life (RUL), which is an important concept in decision making for contingency mitigation. Success in this course requires knowledge of probability theory and statistics, and familiarity with MATLAB/Simulink.

ENGR 4723 Digital Control (4 Credits)
The course focuses on modeling, analysis, and design of digital control systems. Topics include: z-Transform and difference equations; sampling and aliasing; Zero-Order Hold (ZOH); A/D and D/A conversions; pulse transfer function representation; time and frequency domain representations; input/output analysis; analysis of sample data systems; stability; design of discrete-time controllers; introduction to state-space representation. Cross listed with ENGR 3723. Prerequisites: ENGR 3721 and ENGR 3722.

ENGR 4730 Introduction to Robotics (4 Credits)
Introduction to the analysis, design, modeling and application of robotic manipulators. Review of the mathematical preliminaries required to support robot theory. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning, and kinetics. Applications include programming and task planning of a manufacturing robot manipulator. Cross listed with ENGR 3730. Prerequisites: ENME 2520 and MATH 2060 or MATH 2200 or instructor approval.

ENGR 4735 Linear Systems (4 Credits)
This course focuses on linear system theory in time domain. It emphasizes linear and matrix algebra, numerical matrix algebra and computational issues in solving systems of linear algebraic equations, singular value decomposition, eigenvalue-eigenvector and least-squares problems, linear spaces and linear operator theory. It studies modeling and linearization of multi-input/multi-output dynamic physical systems, state-variable and transfer function matrices, analytical and numerical solutions of systems of differential and difference equations, structural properties of linear dynamic physical systems, including controllability, observability and stability. It covers canonical realizations, linear state-variable feedback controller and asymptotic observer design, and the Kalman filter. Cross listed with ENGR 3735. Prerequisites: ENGR 3611, ENGR 3721, ENGR 3722, or permission of the instructor.

ENGR 4740 Adaptive Control Systems (4 Credits)
Theoretical and application aspects of robust adaptive control design for uncertain dynamical systems. Topics include: parameter estimation, stability, model reference adaptive systems, self-tuning regulators, gain scheduling, design for robustness against unmodeled dynamics and disturbance signals. Examples will be given from aerospace engineering (changes in the dynamics of aircraft), process control, and robotics. Modern alternatives to traditional adaptive control will be discussed (switching multi-model/multi-controller adaptive schemes). Prerequisites: ENEE 3111, ENGR 3611, and ENGR 3721, or permission of instructor. Familiarity with MATLAB/Simulink.

ENGR 4745 Adv Non-Linear Control System (4 Credits)
Nonlinear system analysis methods: Existence of solutions of ODEs, uniqueness, continuity, compactness, fixed point, linearization, metric spaces, Contraction Mapping Theorem, Gronwall-Bellman lemma. Phase plane analysis; Limit Cycles. Lyapunov stability of autonomous and non-autonomous systems. Circle criterion, absolute stability, Popov criterion. Passivity and Lyapunov stability. Input-to-State stability. Small Gain Theorem. Describing functions. Nonlinear control system synthesis methods: Passivity-based control. Stability via Feedback Linearization. Lie derivatives.

ENGR 4750 Networked Control Systems (4 Credits)
Fundamental tools and recent advances in networked control. Topics include the control of multi-agent networks found in multi-vehicle coordination, control of sensor networks, unmanned vehicles, and energy systems. Network models, distributed control and estimation, distributed control under limited communications and sensing, formation control, coverage control in mobile sensor networks. Prerequisites: linear algebra, linear control systems, differential equations, familiarity with MATLAB, or permission of instructor.

ENGR 4755 Optimal Control (4 Credits)
Introduction to optimal control theory (control laws that maximize a specified measure of a dynamical system's performance). Topics include: optimality conditions and constraints; calculus of variations; review of mathematical programming (Language multipliers, convexity, Kuhn-Tucker theorem); Pontryagin's maximum principle (constraints, Hamilitonians, bang-bang control); dynamic programming and Linear Quadratic Regulation (Riccati, Hamilton-Jacobi equation). Prerequisites: ENGR 3721 (Controls) and ENGR 3735/4735 (Linear Systems) or equivalent courses.

ENGR 4760 Multivariable Control (4 Credits)
Multivariable aspects of control (systems with multiple actuators and sensors); performance analysis of feedback control systems; sensitivity; robustness and stability margins; disturbance attenuation; design tradeoffs; singular value; characteristic locus. Modern H-infinity control theory and 'mu' synthesis-based robust control design techniques. Enforced Prerequisites and Restrictions ENGR 3721 (Controls) and ENGR 4735 (Linear Systems at a graduate level) or equivalents.

ENGR 4765 Robot Control (4 Credits)
The course focuses on different techniques, methods, and theories for control of robots. The topics covered include: introduction to nonlinear control theory, review of independent joint control, nonlinear and multivariable robot control, feedback linearization control of robots, control of underactuated robots, control of nonholonomic and mobile robots. force and impedance control, and vision-based control. Pre-requisite or co-requisite: ENGR 3730 or ENGR 4730, or equivalent is recommended.

ENGR 4790 Systems Engineering Requirements (4 Credits)
The course covers fundamentals of design and requirements analysis of complex systems to meet overall mission requirements. It spans the whole requirements engineering phase that includes requirements analysis, decomposition, derivation, allocation, verification and validation planning. Students acquire expertise in creating UML and SYML case diagrams and in defining and implementing verification and validation plans. Requirement management methods and tools, associated vernacular, and requirements configuration control are also covered. Prerequisites: ENMT 4100, or permission by the Instructor.

ENGR 4810 Advanced Topics (ENGR) (1-5 Credits)

ENGR 4865 Design, Innovation, and Entrepreneurship (4 Credits)
The course focuses on design and innovation of engineering systems and products. It deals with entrepreneurship, critical and innovative thinking, creativity and lateral thinking, research and technology challenges that lead to innovation, entrepreneurship and new product development, problem solving and decision making. It discusses factors that affect innovation (e.g. tech insertion), as well as a wide range of case studies in diverse application domains. Course Requirements: Projects.

ENGR 4910 Conceptual Design (4 Credits)
Conceptual design is the part of the design process where—by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure— the basic solution path is laid down through the elaboration of a solution principle. Conceptual design specifies the principle solution. Concept design rarely starts at the same point; you might have an existing design that needs iterating or the requirement to create a conceptualized form. Problem solving consists of using generic or ad hoc methods in an orderly manner to find solutions to problems. George Polya (mathematician) presented two important decision-making principles, understanding the problem and devising a plan. To understand what is new, students are asked to look at intellectual property, a category of property that includes intangible creations of the human intellect. There are many types of intellectual property such as patents, and some countries recognize more than others. Designers assess the many different directions a design could take at this stage will allow you to identify what you like and don't like from each one. The preferred concept will then be further developed using engineering drawings, schematics and possibly 3D models which will show how the design will look and operate.

ENGR 4920 Aerospace Missions (4 Credits)
The Design "Problem" in Advanced Aerospace Systems describes the problems in the conceptual design of various types of aircraft, spacecraft, and complex vehicles. It covers the following topics: design of orbital spacecraft, design for Moon missions (such as landers), design for Mars missions (including rovers), design of an unmanned drone for surveillance (high-altitudes), CubeSats (having large constellations), and rockets and missiles (including hypersonic). Problem statements are concise descriptions of design problems. Design teams use them to define the current and ideal states, to freely find user-centered solutions. This class stands as a reference of interest to engineers and scientists working in aerospace engineering and related topics.

ENGR 4940 Mission Operation Controls (4 Credits)
Space operations is based at a centralized control center, a facility used for command & control (C2), and related communication equipment (antennas, etc.). The human operators conduct the day-to-day operations for controlling the spacecraft. They control the spacecraft and its payloads, and carries out all activities related to mission planning and scheduling. For example, normal orbital operations are interrupted every six months to conduct orbital maneuvers. Launch operations begin with spacecraft integration and checked-out for launch. Once safely placed in orbit, command and control goes back and forth between the ground control station and the spacecraft or satellite. A key aspect of spacecraft operations is the transferring of data from the onboard instruments collected by its payload to the ground, eventually disseminating the data to concerned users and analysts through a ground data network. This requires an on-orbit communication architecture.

ENGR 4991 Independent Study (1-5 Credits)

ENGR 4995 Independent Research (1-16 Credits)

ENGR 5991 Independent Study (0-10 Credits)

ENGR 5995 Independent Research (1-16 Credits)

Faculty

Ali Arab, Research Assistant Professor, PhD, University of Houston

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