Master's and Doctoral Degrees

Why study engineering at the University of Denver?

DU's Department of Electrical and Computer Engineering (ECE) is creating the future of technology by providing a graduate education that emphasizes both multi-disciplinary and cross-disciplinary knowledge. The distinguished faculty is creating multi-disciplinary education programs that cover both depth and breadth, and research programs that incorporate and account for technological trends in research and development, along with industry. Graduate students join the faculty in conducting cutting-edge basic and applied research in emerging disciplines developing novel and unique solutions to old and new problems and opportunities.

All laboratories in the Department contain state-of-the-art equipment and software to support basic and applied research in hardware and software design, hardware/software interfacing, communications and signal processing, image processing, computer vision and pattern recognition, optoelectronics, power and energy systems, robotics, mechatronic systems, intelligent systems, unmanned systems, among other research areas. Small classes support our multi-disciplinary and real-time focus by providing close contact between students and faculty, which allows us to meet students' individual career goals.

Denver is a first-rate location for business, government and laboratory partnerships, and technology employment. The Colorado Front Range is consistently rated as one of the top high-tech areas in the country, and DU is located just minutes from the Denver Technological Center, the site of many top technology companies. The Department of Electrical and Computer Engineering is committed to active collaboration with these industry leaders. As a result, our students graduate with relevant research experience and a network of employment contacts in the technology sector that is second to none!

The ECE Department offers, among other degrees, a master's and a PhD degree in Mechatronic Systems Engineering (MSE). DU/ECE is the only University in the United States that offers BS, MS and PhD degrees in MSE.

Doctor of Philosophy in Electrical and Computer Engineering

The objective of the PhD in Electrical and Computer Engineering degree program is to provide an educational environment that encourages students to develop the ability to contribute to the advancement of science, engineering and technology, through independent research. The PhD students of the 21st century may pursue academic, research, entrepreneurial, and/or industrial careers. We offer opportunities to develop individualized plans of study based on the students’ previous experience and desired research areas. The plan of study allows students to work on interdisciplinary research, while also satisfying the PhD in ECE degree requirements.

Research requires an in-depth study of engineering problems with a broad knowledge base in science and engineering. Therefore, advanced courses are offered to strengthen the fundamentals and to broaden the engineering and science perspective. The minimum credit requirements are different for individuals entering a program with a closely related master’s degree and for those entering with a bachelor's only. All requirements for the degree must be completed within seven years (eight years without a master’s degree) from admission to candidacy. A grade of C or better must be obtained in each course in order for that course to count toward the credit hour requirements. An overall minimum GPA of 3.0 is also required for graduation.

The PhD in ECE is appealing to students because it offers the much needed specialization component and the ‘degree identity’ required to be competitive in the job market. Graduates from this program will be well equipped to follow academic careers, or be hired in federal laboratories, industry and the private sector.

Doctor of Philosophy in Mechatronics Systems Engineering

The objective of the PhD in Mechatronics Systems Engineering (MSE) degree program is to provide an educational environment that encourages students to develop the ability to contribute to the advancement of science, engineering and technology, through independent research. The PhD students of the 21st century may pursue academic, research, entrepreneurial, and/or industrial careers. We offer opportunities to develop individualized plans of study based on the students’ previous experience and desired research areas. The plan of study allows students to work on interdisciplinary research, while also satisfying the PhD in MSE degree requirements.

Research requires an in-depth study of engineering problems with a broad knowledge base in science and engineering. Therefore, advanced courses are offered to strengthen the fundamentals and to broaden the engineering and science perspective. The minimum credit requirements are different for individuals entering a program with a closely related master’s degree and for those entering with a bachelor's only. All requirements for the degree must be completed within seven years (eight years without a master’s degree) from admission to candidacy. A grade of C or better must be obtained in each course in order for that course to count toward the credit hour requirements. An overall minimum GPA of 3.0 is also required for graduation.
The PhD in MSE is at the forefront and intersection of the coupled disciplines of Electrical, Mechanical, Computer Engineering, and Computer Science. This unique degree is appealing to students because they will acquire the knowledge and ability to deal with and solve highly complex problems where integration is a key component. This degree provides a holistic approach to graduate education focusing on the ability to cover both breadth and depth of knowledge. Graduates of this program will lay the foundation for the modern engineering departments of the future, where ‘integration’ will be the key ingredient of studies.

**Master of Science in Computer Engineering**

The Master of Science in Computer Engineering (MSCpE) is designed to advance the student’s knowledge in several areas of engineering. This degree provides breadth while permitting the student to achieve depth in a specialization area. This specialization area, with thematic sequences of courses, has been selected to coincide with those of high current interest as well as those emerging technologies that hold promise of increasing importance for the future. The purpose of this program is to serve the profession of engineering and the Colorado community through advanced study in computer engineering, electrical engineering, and other related fields. This program prepares the student for academic and industrial advancement. The program offer a thesis and a non-thesis option.

The Department of ECE offers both part-time and full-time programs. The Department recognizes that a student may be employed full-time while studying for a degree. Therefore, most courses are offered at times and on days that will permit a student to complete the program by taking courses either late in the day or outside normal business hours. The MSCpE program can generally be completed in about four years if one course is taken each quarter, but it is usually possible to take two courses per quarter, bringing completion time closer to the more common duration of two years. Also, students who select the one-year non-thesis will be able to graduate within 12 months, four academic quarters. For part-time students who are working in industry positions and who have chosen the thesis option, a topic related to the job function may be acceptable as the thesis research topic. Furthermore, a qualified staff member at the place of employment may be approved to serve as an adjunct faculty on the thesis committee.

Students not interested in pursuing a degree but interested in taking an occasional course may register as special status students by following an abbreviated admissions process. However, only 15 QH earned as a special status student may be applied toward a MS degree.

**Master of Science in Electrical Engineering**

The Master of Science in Electrical Engineering (MSEE) is designed to advance the student’s knowledge in several areas of engineering. This degree provides breadth while permitting the student to achieve depth in a specialization area. This specialization area, with thematic sequences of courses, has been selected to coincide with those of high current interest as well as those emerging technologies that hold promise of increasing importance for the future. The purpose of this program is to serve the profession of engineering and the Colorado community through advanced study in computer engineering, electrical engineering, and other related fields. This program prepares the student for academic and industrial advancement. The program offer a thesis and a non-thesis option.

The Department of ECE offers both part-time and full-time programs. The Department recognizes that a student may be employed full-time while studying for a degree. Therefore, most courses are offered at times and on days that will permit a student to complete the program by taking courses either late in the day or outside normal business hours. The MS degree program can generally be completed in about four years if one course is taken each quarter, but it is usually possible to take two courses per quarter, bringing completion time closer to the more common duration of two years. Also, students who select the one-year non-thesis will be able to graduate within 12 months, four academic quarters. For part-time students who are working in industry positions and who have chosen the thesis option, a topic related to the job function may be acceptable as the thesis research topic. Furthermore, a qualified staff member at the place of employment may be approved to serve as an adjunct faculty on the thesis committee.

Students not interested in pursuing a degree but interested in taking an occasional course may register as special status students by following an abbreviated admissions process. However, only 15 QH earned as a special status student may be applied toward a MS degree.

**Master of Science in Mechatronic Systems Engineering**

The Master of Science in Mechatronic Systems Engineering (MSMSE) is designed to advance the student’s knowledge in several areas of engineering. This degree provides breadth while permitting the student to achieve depth in a specialization area. This specialization area, with thematic sequences of courses, has been selected to coincide with those of high current interest as well as those emerging technologies that hold promise of increasing importance for the future. The purpose of this program is to serve the profession of engineering and the Colorado community through advanced study in computer engineering, electrical engineering, and other related fields. This program prepares the student for academic and industrial advancement. The program offer a thesis and a non-thesis option.

The Department of ECE offers both part-time and full-time programs. The Department recognizes that a student may be employed full-time while studying for a degree. Therefore, most courses are offered at times and on days that will permit a student to complete the program by taking courses either late in the day or outside normal business hours. The MS degree program can generally be completed in about four years if one course is taken each quarter, but it is usually possible to take two courses per quarter, bringing completion time closer to the more common duration of two years. Also, students who select the one-year non-thesis will be able to graduate within 12 months, four academic quarters. For part-time students who are working in industry positions and who have chosen the thesis option, a topic related to the job function may be acceptable as the thesis research topic. Furthermore, a qualified staff member at the place of employment may be approved to serve as an adjunct faculty on the thesis committee.

Students not interested in pursuing a degree but interested in taking an occasional course may register as special status students by following an abbreviated admissions process. However, only 15 QH earned as a special status student may be applied toward a MS degree.
Master of Science in Systems Engineering (Online)
This Master of Science degree in Systems Engineering (MSSY) along with the three Specialized Graduate Certificates will cover the depth and breadth in systems design, analysis, synthesis, integration, testing, validation, and verification. We will train our students with expertise in fundamentals of the discipline of systems engineering. Our program will have emphasis on support for proposals after contract award, through critical design reviews, as well as system design and integration and associated validation and verification activities, which are necessarily traceable to system requirements. We will also provide practical exposure to the analytical and digital tools which are paramount to the evolving practice of systems engineering. This practical exposure is designed to enable the student to participate in rigorous post-test data analysis, to participate in model based design and model based systems engineering, as well as statistically relevant process improvement projects. Learned skills, knowledges and case studies will be applicable to engineering professionals in many industries, particularly regulated industries such as aerospace, biomedical, and autonomous vehicles.

The program is built for graduate students and industry professionals. The MSSY program is comprised of three Stackable Certificates that lead to the MS degree in Systems Engineering degree: (1) Fundamentals of Systems Engineering; (2) Systems Design & Architecture; (3) Systems Analytics and Practice. The program is delivered primarily online.

The MS degree program can generally be completed in about three years if two courses are taken each quarter, with each certificate being completed in a year.

Students not interested in pursuing a degree but interested in taking an occasional course may register as special status students by following an abbreviated admissions process. However, only 9 QH earned as a special status student may be applied toward a MS degree.

Doctor of Philosophy in Electrical & Computer Engineering
Degree and GPA Requirements
- Bachelor’s degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.
- Grade point average: The minimum undergraduate GPA for admission consideration for graduate study at the University of Denver is a cumulative 2.5 on a 4.0 scale or a 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree. An earned master’s degree or higher from a regionally accredited institution supersedes the minimum standards for the baccalaureate. For applicants with graduate coursework but who have not earned a master’s degree or higher, the GPA from the graduate work may be used to meet the requirement. The minimum GPA is a cumulative 3.0 on a 4.0 scale for all graduate coursework undertaken.
- Program GPA requirement: The minimum undergraduate GPA for admission consideration for this program is a cumulative 2.5 on a 4.0 scale.

Prerequisites
- Students with a MS in CpE, MS in MSE, MS in EE, MS in ME, or closely related areas may apply for admission to the PhD in ECE or PhD in MSE programs. Admission with only a BS in this field is also possible, but students with only a BS degree are strongly encouraged to enroll first in the MS (CpE, EE, MSE) programs. All graduate engineering courses presuppose mastery of the subject matter of a modern ABET-accredited curriculum in engineering. Students with a BS in other engineering or related science fields and students with a BSCpE, BSEE, or BSME who have not taken graduate academic work for some time may be required to complete preparatory courses that are prerequisites for the core courses of the engineering concentrations on which the qualifying exams are based. These courses carry no credit toward the graduate degree.

English Language Proficiency Test Score Requirements
The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:
- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

English Conditional Admission: No, this program does not offer English Conditional Admission.

Doctor of Philosophy in Mechatronic Systems Engineering
Degree and GPA Requirements
- Bachelor’s degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.
- Grade point average: The minimum undergraduate GPA for admission consideration for graduate study at the University of Denver is a cumulative 2.5 on a 4.0 scale or a 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree. An earned master’s degree or higher from a regionally accredited institution supersedes the minimum standards for the baccalaureate. For applicants with graduate coursework but who have not earned a master’s degree or higher, the GPA from the graduate work may be used to meet the requirement. The minimum GPA is a cumulative 3.0 on a 4.0 scale for all graduate coursework undertaken.
- Program GPA requirement: The minimum undergraduate GPA for admission consideration for this program is a cumulative 2.5 on a 4.0 scale.
Prerequisites

- Students with a MS in CpE, MS in MSE, MS in EE, MS in ME, or closely related areas may apply for admission to the PhD in ECE or PhD in MSE programs. Admission with only a BS in this field is also possible, but students with only a BS degree are strongly encouraged to enroll first in the MS (CpE, EE, MSE) programs. All graduate engineering courses presuppose mastery of the subject matter of a modern ABET-accredited curriculum in engineering. Students with a BS in other engineering or related science fields and students with a BScpE, BSEE, or BSME who have not taken graduate academic work for some time may be required to complete preparatory courses that are prerequisites for the core courses of the engineering concentrations on which the qualifying exams are based. These courses carry no credit toward the graduate degree.

Other Required Materials

- We recommend PhD applicants contact faculty to find a research advisor BEFORE submitting the application. If we receive an application and there is no research advisor commitment, we will consider the applicant for the master's program only.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

English Conditional Admission: No, this program does not offer English Conditional Admission.

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Master of Science in Electrical Engineering, Computer Engineering or Mechatronic Systems Engineering

Degree and GPA Requirements

- Bachelor's degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.
- Grade point average: The minimum undergraduate GPA for admission consideration for graduate study at the University of Denver is a cumulative 2.5 on a 4.0 scale or a 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree. An earned master's degree or higher from a regionally accredited institution supersedes the minimum standards for the baccalaureate. For applicants with graduate coursework but who have not earned a master's degree or higher, the GPA from the graduate work may be used to meet the requirement. The minimum GPA is a cumulative 3.0 on a 4.0 scale for all graduate coursework undertaken.
- Program GPA requirement: The minimum undergraduate GPA for admission consideration for this program is a cumulative 2.5 on a 4.0 scale.

Prerequisites

- A Bachelor of Science (BS) degree in computer engineering (BScpE), electrical engineering (BSEE), or closely related field from a regionally accredited college or university is required for admission to the programs. Those students whose backgrounds differ significantly from EAC/ABET-accredited BS computer, electrical, or computer programs may be required to complete prerequisite undergraduate courses. Such courses are not considered part of the 45 course hour requirements for the degree. A competency examination may be required of candidates who do not possess a 3.0 GPA or a BS in electrical, electronic, or computer from an EAC/ABET accredited program. Students with BS degrees in physics, mathematics, computer science, engineering science, electrical engineering technology, engineering physics, or similar BS degrees from a regionally accredited college or university may also be admitted. However, these students should be able to demonstrate competency in the following basic subjects by passing an appropriate competency examination: MSCpE: Circuits and Electronics, Digital Systems, Computer Organization, a high- or low-level computer language; MSEE: Digital Design Methods, Physical Electronics, Introductory Electromagnetics, Signals and Systems, Principles of Communications, Circuits and Electronics; MSE: Controls, Robotics, Signals and Systems, Circuits and Electronics, Digital Design Methods, Mechanics, Electromagnetics.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

English Conditional Admission: No, this program does not offer English Conditional Admission.
Masters of Science in Systems Engineering (Online)

Degree and GPA Requirements

- Bachelor’s degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.
- Grade point average: The minimum undergraduate GPA for admission consideration for graduate study at the University of Denver is a cumulative 2.5 on a 4.0 scale or a 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree. An earned master’s degree or higher from a regionally accredited institution supersedes the minimum standards for the baccalaureate. For applicants with graduate coursework but who have not earned a master’s degree or higher, the GPA from the graduate work may be used to meet the requirement. The minimum GPA is a cumulative 3.0 on a 4.0 scale for all graduate coursework undertaken.
- Program GPA requirement: The minimum undergraduate GPA for admission consideration for this program is a cumulative 2.5 on a 4.0 scale.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

English Conditional Admission: No, this program does not offer English Conditional Admission.

Specialized Graduate Certificate in Fundamentals of Systems Engineering

Degree and GPA Requirements

- Bachelor’s degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.
- Grade point average: The minimum undergraduate GPA for admission consideration for graduate study at the University of Denver is a cumulative 2.5 on a 4.0 scale or a 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree. An earned master’s degree or higher from a regionally accredited institution supersedes the minimum standards for the baccalaureate. For applicants with graduate coursework but who have not earned a master’s degree or higher, the GPA from the graduate work may be used to meet the requirement. The minimum GPA is a cumulative 3.0 on a 4.0 scale for all graduate coursework undertaken.
- Program GPA requirement: The minimum undergraduate GPA for admission consideration for this program is a cumulative 2.5 on a 4.0 scale.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

English Conditional Admission: No, this program does not offer English Conditional Admission.

Specialized Graduate Certificate in Systems Design and Architecture

Degree and GPA Requirements

- Bachelor’s degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.
- Grade point average: The minimum undergraduate GPA for admission consideration for graduate study at the University of Denver is a cumulative 2.5 on a 4.0 scale or a 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree. An earned master’s degree or higher from a regionally accredited institution supersedes the minimum standards for the baccalaureate. For applicants with graduate coursework but who have not earned a master’s degree or higher, the GPA from the graduate work may be used to meet the requirement. The minimum GPA is a cumulative 3.0 on a 4.0 scale for all graduate coursework undertaken.
- Program GPA requirement: The minimum undergraduate GPA for admission consideration for this program is a cumulative 2.5 on a 4.0 scale.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:
• Minimum TOEFL Score (Internet-based test): 80
• Minimum IELTS Score: 6.5
• Minimum C1 Advanced Score: 176
• Minimum Duolingo English Test Score: 115

English Conditional Admission: No, this program does not offer English Conditional Admission.

Doctoral Degree Programs
Doctor of Philosophy in Electrical and Computer Engineering

Program requirements
All PhD students who have been admitted to the PhD in ECE program must successfully complete three milestones before the PhD degree can be conferred. These milestones refer to:

• Demonstrating that the student is qualified to begin PhD studies
• Demonstrating that the student may identify and formulate a research problem
• Demonstrating that the student can defend her/his dissertation

These three milestones are referred to as the “PhD Qualifying Exam”, the “Comprehensive Exam” (also known as the “PhD Proposal”), and the “Dissertation Defense”, respectively.

Coursework requirements
The PhD in ECE does not have specific course requirements. The coursework plan needs to be approved by the student’s advisor and the department chair.

Graduate Assessment Requirement
ECE Graduate Assessment (ENEE 4950)

This graduate assessment course is required for all ECE graduate students to be taken in their last quarter (the term they have applied as the graduation term). All required assessment materials are uploaded to the course Assignments online 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. As part of the graduate assessment effort, students’ advisors and members of Master's thesis Committee / PhD Committee will be asked to provide related information online.

Specifically, (1) Master’s degree thesis-option students are required to complete a written self-reflection essay on entire MS program including thesis research and upload the final OGE approved thesis, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (2) Master’s degree non-thesis-option students are required to complete a written self-reflection essay on entire MS program and upload an assembled portfolio that includes reports from at least two course projects or homework from the core or depth courses, presentation slides from any course projects, along with the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (3) PhD students are required to complete a written self-reflection essay on entire PhD program including dissertation research and upload the final OGE approved dissertation, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation.

Minimum credit requirements
Students with a Bachelor of Science in Engineering/Science

For students admitted to the PhD program with a bachelor’s degree, 90 QH are required, 75 of which must be completed at the University of Denver. A minimum of 48 QH must be at the 4000-level or higher and may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by the advisor and department chair. The student with his/her advisor will develop an appropriate plan of study with core requirements, an area of specialization (depth requirement), breadth requirement and advanced mathematics. The core will consist of 8 QH of coursework. The area of specialization will consist of 16 QH of coursework. An additional 6 QH of coursework (excluding independent research) is required as related breadth requirement. The student must complete a minimum of 16 QH at the 4000-level courses, excluding independent research. Prior to completion of the comprehensive exam, the plan of study must be approved by the student’s PhD committee and the chair.

If a student is entering the PhD program without a relevant master’s degree, the student should work with his/her advisor in order to meet the degree requirements for a master’s degree. All requirements for the given master’s degree must be met.

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Breadth Requirement

Students with a Master of Science in Engineering/Science

If a student is admitted with a closely related master’s degree, up to 45 hours may be transferred and applied to the doctorate degree. The student with his or her advisor will develop an appropriate program consisting of a minimum of 28 quarter hours at the 4000-level, which may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by the advisor and the department chair. The student with his or her advisor will develop an appropriate plan of study with an area of specialization, breadth requirements and advanced mathematics. Prior to completion of the comprehensive exam, the student’s plan of study must be approved by the student’s PhD committee and the department chair.

Non-coursework Requirements

Qualifying Examination

Each student must demonstrate sufficient breadth and depth of basic engineering knowledge relevant to electrical and computer engineering and be able to demonstrate ability to organize and present her/his thoughts in a convincing manner. To achieve this, each admitted student is required to demonstrate proficiency in five chosen courses by receiving a final grade of B or better. Students may either enroll or test out these courses. These criteria do not necessarily have to be met within a single quarter; however, a maximum of two attempts is allowed for each course or test.

The five courses will be one from the list of Core Courses, two from two Subject Area Courses, and two courses approved by the advisor. The list of courses is subject to modification with the approval of the department.

Core Courses - Choose one course

Subject Area Courses – choose two courses from two areas

Circuits, Electronics and Electromagnetics

Computer Engineering

Control and Communication Systems

Biomedical Engineering

ENGR 4100 Instrumentation and Data Acquisition
ENEE 3011 Physical Electronics
ENEE 3641 Introduction to Electromagnetic Compatibility
ENEE 4030 Optoelectronics
ENCE 4110 Modern Digital Systems Design
ENCE 3231 Embedded Systems Programming
ENCE 3321 Network Design
ENCE 4631 Advanced Machine Learning
ENCE 3670 Introduction to Digital Signal Processing
ENGR 3721 Controls
ENGR 4723 Digital Control
ENGR 4735 Linear Systems
ENGR 4740 Adaptive Control Systems
ENGR 3450 Biosensing Technology
ENGR 4455  Fluorescence and its applications in biomedical sensors
ENBI 4620  Bioelectronics
ENEE 4630  Optical Networking

Robots
ENCE 4620  Advanced Computer Vision
ENGR 4730  Introduction to Robotics

Power and Energy Systems
ENGR 3510  Renewable and Efficient Power and Energy Systems
ENGR 4530  Intro to Power and Energy

Qualifier Transfer Policy

Policy Statement
The Electrical and Computer Engineering (ECE) Department at Denver University (DU) acknowledges the Qualifying Exam achievements of PhD students transferring from other institutions. Subject to the student having successfully passed the Qualifying Exam at their original institution and upon receiving endorsement from their advisor, the departmental faculty will consider and vote on granting an exemption from the DU ECE Qualifying Exam on a case-by-case basis. A majority decision will be required for approval.

This policy applies exclusively to PhD students transferring to DU ECE under the guidance of their advisor. This scenario primarily arises when the department seeks to attract top talent, with advisors bringing only those students who have already demonstrated their qualifications. In alignment with our strategy to recruit outstanding individuals, it is appropriate for the ECE Department to recognize and accept the results of Qualifying Exams from other reputable institutions. This approach allows both faculty and newly admitted students to devote their efforts towards achieving significant research contributions for the department.

Timeline
Each admitted graduate student must complete/satisfy all Qualifying Exam requirements within at most 5 quarters from initial admittance. Failure to pass any component of the PhD Qualifying Exam within the given time constraints will prevent the student from continuing in the PhD program.

Comprehensive Examination
The purpose of the Comprehensive Examination is to ascertain the potential of the student for PhD quality research. At least two quarters prior to the final defense, the student shall schedule and take the Comprehensive Examination. This oral and written examination will be attended by a minimum of three faculty members, the same faculty who will attend the student’s final dissertation defense. The Comprehensive Exam may be open to other students based on the requirements of the student’s advisor. The student is expected to make a 30 to 40 minute concise presentation on her/his dissertation topic. The oral and written presentation will highlight previous work in this area, demonstrate a need for the given research, and explain how the given research will contribute to the advancement of the area. The student will also present completed work and results, anticipated work and results, and a detailed plan for project completion. In addition, the student will be expected to answer general fundamental questions in the area of her/his concentration and detailed questions in the area of the student’s graduate course work.

The PhD Qualifying Examination must be taken and passed prior to the student taking the Comprehensive Examination. The Comprehensive Examination can be taken at most 2 times. If the student does not pass the Comprehensive Exam on the second try, the student will be terminated from the program. The comprehensive exam will be graded on a pass/fail system.

Dissertation
The student is required to complete and defend a dissertation of publishable quality based on the student’s original research. The dissertation must be completed in written form in accordance with the University’s Graduate School guidelines. A summary of the dissertation must be presented in a public seminar and subsequently defended by the student in the final oral defense. The defense committee will consist of the student’s entire PhD committee.

Residence Requirement
Enrollment in at least six quarters (four semesters), including at least two consecutive quarters (one semester) of full-time attendance is required for graduation.

PhD Committee
The PhD committee should consist of at least four faculty members. Three faculty members must be from within the student’s specialty area; these can include the student’s advisor, other faculty in that degree program and, if necessary, off-campus experts. Finally, for the final oral defense of the dissertation, an oral defense chair, who must be a tenured faculty member outside the Department of Electrical and Computer Engineering and Mechanical and Materials Engineering, needs to be identified in consultation with the DU Graduate Studies Office. The PhD committee needs to be identified with the dissertation advisor and approved by the chair of the department and the Office of Graduate Studies.
Doctor of Philosophy in Mechatronics Systems Engineering

Program requirements
All PhD students who have been admitted to the PhD in ECE or PhD in MSE programs must successfully complete three milestones before the PhD degree can be conferred. These milestones refer to:

- Demonstrating that the student is qualified to begin PhD studies
- Demonstrating that the student may identify and formulate a research problem
- Demonstrating that the student can defend her/his dissertation

These three milestones are referred to as the “PhD Qualifying Exam”, the “Comprehensive Exam” (also known as the “PhD Proposal”), and the “Dissertation Defense”, respectively.

Coursework requirements
The PhD in MSE does not have specific course requirements. The coursework plan needs to be approved by the student’s advisor and the department chair.

Graduate Assessment Requirement
ECE Graduate Assessment (ENEE 4950)

This graduate assessment course is required for all ECE graduate students to be taken in their last quarter (the term they have applied as the graduation term). All required assessment materials are uploaded to the course Assignments online 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. As part of the graduate assessment effort, students’ advisors and members of Master's thesis Committee / PhD Committee will be asked to provide related information online.

Specifically, (1) Master’s degree thesis-option students are required to complete a written self-reflection essay on entire MS program including thesis research and upload the final OGE approved thesis, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (2) Master’s degree non-thesis-option students are required to complete a written self-reflection essay on entire MS program and upload an assembled portfolio that includes reports from at least two course projects or homework from the core or depth courses, presentation slides from any course projects, along with the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (3) PhD students are required to complete a written self-reflection essay on entire PhD program including dissertation research and upload the final OGE approved dissertation, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation.

Minimum credit requirements
Students with a Bachelor of Science in Engineering/Science
For students admitted to the PhD program with a bachelor’s degree, 90 QH are required, 75 of which must be completed at the University of Denver. A minimum of 48 QH must be at the 4000-level or higher and may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by advisor and assuming a minimum of 16 QH are earned excluding independent research

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEE 4950</td>
<td>ECE Graduate Assessment</td>
<td>0</td>
</tr>
</tbody>
</table>

A minimum of 48 QH must be at the 4000-level or higher, may include Independent Research or Independent Study as considered appropriate by advisor and assuming a minimum of 16 QH are earned excluding independent research

Core Requirement

Depth Requirement - Specialization Area

Breadth Requirement

Total Credits

1 The breadth requirement must be pre-approved by the student’s advisor.

Students with a Master of Science in Engineering/Science
If a student is admitted with a closely related master’s degree, the student should work with their advisor in order to meet the degree requirements for a master’s degree. All requirements for the given master’s degree must be met.
dissertation research hours (Independent Research and Independent Study) as considered appropriate by the advisor. The student with his or her advisor will develop an appropriate plan of study with an area of specialization, breadth requirements and advanced mathematics. Prior to completion of the comprehensive exam, the student’s plan of study must be approved by the student’s PhD committee.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEE 4950</td>
<td>ECE Graduate Assessment</td>
<td>0</td>
</tr>
<tr>
<td>A minimum of 36QH must be at the 4000-level or higher, may include Independent Research or Independent Study as considered appropriate by advisor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student with his or her advisor will develop an appropriate plan of study with an area of specialization, breadth requirements and advanced mathematics.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total Credits</strong></td>
<td>90</td>
</tr>
</tbody>
</table>

**Non-coursework Requirements**

**Qualifying Examination**

Each student must demonstrate sufficient breadth and depth of basic engineering knowledge relevant to electrical and computer engineering and be able to demonstrate ability to organize and present her/his thoughts in a convincing manner. To achieve this, each admitted student is required to demonstrate proficiency in five chosen courses by receiving a final grade of B or better. Students may either enroll or test out these courses. These criteria do not necessarily have to be met within a single quarter; however, a maximum of two attempts is allowed for each course or test.

The five courses will be one from the list of Core Courses, two from two Subject Area Courses, and two courses approved by the advisor. The list of courses is subject to modification with the approval of the department.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 3151</td>
<td>Advanced Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3650</td>
<td>Probability and Statistics for Engineers</td>
<td></td>
</tr>
<tr>
<td>ENGR 3621</td>
<td>Advanced Engineering Mathematics</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Subject Area Courses – choose two courses from two areas</strong></td>
<td>16</td>
</tr>
<tr>
<td>ENGR 3450</td>
<td>Renewable and Efficient Power and Energy Systems</td>
<td></td>
</tr>
</tbody>
</table>
Qualifier Transfer Policy

Policy Statement

The Electrical and Computer Engineering (ECE) Department at Denver University (DU) acknowledges the Qualifying Exam achievements of PhD students transferring from other institutions. Subject to the student having successfully passed the Qualifying Exam at their original institution and upon receiving endorsement from their advisor, the departmental faculty will consider and vote on granting an exemption from the DU ECE Qualifying Exam on a case-by-case basis. A majority decision will be required for approval.

This policy applies exclusively to PhD students transferring to DU ECE under the guidance of their advisor. This scenario primarily arises when the department seeks to attract top talent, with advisors bringing only those students who have already demonstrated their qualifications. In alignment with our strategy to recruit outstanding individuals, it is appropriate for the ECE Department to recognize and accept the results of Qualifying Exams from other reputable institutions. This approach allows both faculty and newly admitted students to devote their efforts towards achieving significant research contributions for the department.

Timeline

Each admitted graduate student must complete/satisfy all Qualifying Exam requirements within at most 5 quarters from initial admittance. Failure to pass any component of the PhD Qualifying Exam within the given time constraints will prevent the student from continuing in the PhD program.

Comprehensive Examination

The purpose of the Comprehensive Examination is to ascertain the potential of the student for PhD quality research. At least two quarters prior to the final defense, the student shall schedule and take the Comprehensive Examination. This oral and written examination will be attended by a minimum of three faculty members, the same faculty who will attend the student’s final dissertation defense. The Comprehensive Exam may be open to other students based on the requirements of the student’s advisor. The student is expected to make a 30 to 40 minute concise presentation on her/his dissertation topic. The oral and written presentation will highlight previous work in this area, demonstrate a need for the given research, and explain how the given research will contribute to the advancement of the area. The student will also present completed work and results, and a detailed plan for project completion. In addition, the student will be expected to answer general fundamental questions in the area of her/his concentration and detailed questions in the area of the student’s graduate course work.

The PhD Qualifying Examination must be taken and passed prior to the student taking the Comprehensive Examination. The Comprehensive Examination can be taken at most 2 times. If the student does not pass the Comprehensive Exam on the second try, the student will be terminated from the program. The comprehensive exam will be graded on a pass/fail system.

Dissertation

The student is required to complete and defend a dissertation of publishable quality based on the student’s original research. The dissertation must be completed in written form in accordance with the University’s Graduate School guidelines. A summary of the dissertation must be presented in a public seminar and subsequently defended by the student in the final oral defense. The defense committee will consist of the student’s entire PhD committee.

Residence Requirement

Enrollment in at least six quarters (four semesters), including at least two consecutive quarters (one semester) of full-time attendance is required for graduation.

PhD Committee

The PhD committee should consist of at least four faculty members. Three faculty members must be from within the student’s specialty area; these can include the student’s advisor, other faculty in that degree program and, if necessary, off-campus experts. Finally, for the final oral defense of the thesis, an oral defense chair, who must be a tenured faculty member outside the Department of Electrical and Computer Engineering and Mechanical and Materials Engineering, needs to be identified in consultation with the DU Graduate Studies Office. The PhD committee needs to be identified with the dissertation advisor and approved by the chair of the department and the Office of Graduate Studies.

Master’s Degree Programs

Master of Science in Computer Engineering

Minimum Credit Requirements

Every candidate for the MS degree must complete 45 QH of credit, at least 36 of which must be completed at the University of Denver.

Program Structure

Candidates may elect either the thesis or non-thesis option. This choice may be made at any time, although a delay in declaration may impact the completion date. Students who are GTAs or who receive financial support from a University research grant, such as GRAs, are required to elect the thesis option. The program is designed to be completed in about six quarters if two courses (usually 8 QH) are taken each quarter.
Electrical and Computer Engineering

Graduate Assessment Requirement

ECE Graduate Assessment (ENEE 4950)

This graduate assessment course is required for all ECE graduate students to be taken in their last quarter (the term they have applied as the graduation term). All required assessment materials are uploaded to the course Assignments online 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. As part of the graduate assessment effort, students' advisors and members of Master's thesis Committee / PhD Committee will be asked to provide related information online.

Specifically, (1) Master's degree thesis-option students are required to complete a written self-reflection essay on entire MS program including thesis research and upload the final OGE approved thesis, defense presentation slides, and the completed and signed degree program plan, by the published OGE "Deadline for thesis/dissertation formatting approval" of the students' last quarter before graduation. (2) Master's degree non-thesis-option students are required to complete a written self-reflection essay on entire MS program and upload an assembled portfolio that includes reports from at least two course projects or homework from the core or depth courses, presentation slides from any course projects, along with the completed and signed degree program plan, by the published OGE "Deadline for thesis/dissertation formatting approval" of the students' last quarter before graduation. (3) PhD students are required to complete a written self-reflection essay on entire PhD program including dissertation research and upload the final OGE approved dissertation, defense presentation slides, and the completed and signed degree program plan, by the published OGE "Deadline for thesis/dissertation formatting approval" of the students' last quarter before graduation.

Non-Thesis Option

The non-thesis option is the more flexible of the two options. This program is designed with the working professional in mind. For this option, a grade of C- or better must be obtained in each course in order for that course to count toward the requirement of 45 QH. An overall minimum GPA of 3.0 is also required for graduation. Students may only take up to 8 quarter hours of independent study to be counted toward the degree, after approval by their advisor and the Chair. Each student must take a minimum of 24 quarter hours at the 4000-level.

One Year (four quarters) – Non-thesis Option

The Department of Electrical and Computer Engineering (ECE) offers a one-year, non-thesis option. Students who select the one-year program will be able to graduate within 12 months, four academic quarters, as there are enough courses offered in each specialization to meet the 20 QH depth requirement. The breadth requirement (14 QH) is fulfilled by taking courses offered in other specializations. In addition, every year courses that satisfy the mathematics requirement (3 QH) are offered. The MS non-thesis structure is shown below. QH in each category denote minimum requirements that must be satisfied. Any changes in the student's plan of study must be approved a-prior by the student's advisor.

The basic structure of the minimum 45 QH for the non-thesis option is as follows:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graduate Assessment Requirement</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Core Requirement</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Depth Requirement - Specialization Area</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Mathematics Requirement (requires one approved course at the 3000-level or higher)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Breadth Requirement</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><strong>Total Credits</strong></td>
<td><strong>45</strong></td>
</tr>
</tbody>
</table>

This indicates minimum number of quarter hours. Any credits over the 3 QH from the mathematics courses will count toward the breadth requirement.

Thesis Option

A thesis permits a candidate to obtain depth in an area of study and it is especially useful for individuals who seek to pursue a subsequent degree, for example, a PhD degree. Thesis candidates work closely with a thesis advisor. The thesis option is required for all GRAs and GTAs. For this option, a grade of C- or better must be obtained in each course in order for that course to count toward the 45 QH hour requirements. An overall minimum GPA of 3.0 is also required for graduation. Students may only take up to 8 quarter hours of independent study to be counted toward the degree. Each student must take a minimum of 16 quarter hours at the 4000-level. The basic structure of the minimum 45 QH for the thesis option is as follows:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graduate Assessment Requirement</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Core Requirement</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Depth Requirement - Specialization Area</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Breadth Requirement</td>
<td>6</td>
</tr>
</tbody>
</table>
Thesis

Total Credits

15

1 The breadth requirement must be pre-approved by the student’s advisor.

If a student who has elected to pursue a thesis option, then at any time thereafter elects to change to a non-thesis option, all requirements for the non-thesis must be met. Any independent research taken may be forfeited and students must adhere to the grade requirements of the non-thesis option.

Breadth Requirement (Non-Thesis and Thesis Option)

Breadth Requirement courses (each with not less than 3 QH of credit) may be chosen from courses offered in other specialization areas. A course that appears in more than one specialization area may only be counted toward either the specialization requirement or the breadth requirement. The remaining courses are chosen from appropriate courses numbered 3000 or higher, offered by the Department Mechanical & Materials Engineering, Department of Computer Science or NSM (Natural Sciences and Mathematics). Prior approval by the student’s advisor is required. It is strongly recommended that students choose math related courses to satisfy the breadth requirement.

The MSCpE program offers one area of specialization:

- Computer Systems Engineering

The student’s degree program will be a combination of the core courses, specialization areas (depth requirement) and the breadth requirement. Each student is required to complete the 2 core courses. Students may choose from any of the courses from their area of specialization but should keep in mind the 4000-level requirement of the degree.

Core courses for all Computer Engineering Students

The following courses are required for all computer engineering students:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEE 4950</td>
<td>ECE Graduate Assessment</td>
<td>0</td>
</tr>
<tr>
<td>ENCE 4110</td>
<td>Modern Digital Systems Design</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3621</td>
<td>Advanced Engineering Mathematics</td>
<td>4</td>
</tr>
</tbody>
</table>

Specialization in Computer Systems Engineering

This area of specialization prepares students with fundamental and working knowledge of methods for analysis, design, and implementation of intelligent systems (IS). Particular attention is given to signal and information processing in IS, design of IS, and implementation of IS using state-of-the-art technology. This is accomplished through several theoretical courses and applied courses. Students must choose from the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENCE 3321</td>
<td>Network Design</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4231</td>
<td>Embedded Systems Programming</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4250</td>
<td>Advanced Hardware Description Language (HDL) Modeling and Synthesis</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4620</td>
<td>Advanced Computer Vision</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4630</td>
<td>Advanced Pattern Recognition</td>
<td>4</td>
</tr>
<tr>
<td>ENEE 3670</td>
<td>Introduction to Digital Signal Processing</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4622</td>
<td>Advanced Optimization</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4631</td>
<td>Advanced Machine Learning</td>
<td>4</td>
</tr>
</tbody>
</table>

Master of Science in Electrical Engineering

The Master of Science in Electrical Engineering (MSEE) is designed to advance the student’s knowledge in several areas of engineering. This degree provides breadth while permitting the student to achieve depth in a specialization area. This specialization area, with thematic sequences of courses, has been selected to coincide with those of high current interest as well as those emerging technologies that hold promise of increasing importance for the future. The purpose of this programs is to serve the profession of engineering and the Colorado community through advanced study in computer engineering, electrical engineering, and other related fields. This program prepares the student for academic and industrial advancement. The program offer a thesis and a non-thesis option.

The Department of ECE offers both part-time and full-time programs. The Department recognizes that a student may be employed full-time while studying for a degree. Therefore, most courses are offered at times and on days that will permit a student to complete the program by taking courses either late in the day or outside normal business hours. The MS degree program can generally be completed in about four years if one course is taken each quarter, but it is usually possible to take two courses per quarter, bringing completion time closer to the more common duration of two years. Also, students who select the one-year non-thesis will be able to graduate within 12 months, four academic quarters. For part-time students who are
working in industry positions and who have chosen the thesis option, a topic related to the job function may be acceptable as the thesis research topic. Furthermore, a qualified staff member at the place of employment may be approved to serve as an adjunct faculty on the thesis committee.

Students not interested in pursuing a degree but interested in taking an occasional course may register as special status students by following an abbreviated admissions process. However, only 15 QH earned as a special status student may be applied toward a MS degree.

**Minimum Credit Requirements**
Every candidate for the MS degree must complete 45 QH of credit, at least 36 of which must be completed at the University of Denver.

**Program Structure**
Candidates may elect either the thesis or non-thesis option. This choice may be made at any time, although a delay in declaration may impact the completion date. Students who are GTAs or who receive financial support from a University research grant, such as GRAs, are required to elect the thesis option. The program is designed to be completed in about six quarters if two courses (usually 8 QH) are taken each quarter.

**Required Graduate Assessment Course**
**ECE Graduate Assessment (ENEE 4950)**
This graduate assessment course is required for all ECE graduate students to be taken in their last quarter (the term they have applied as the graduation term). All required assessment materials are uploaded to the course Assignments online 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. As part of the graduate assessment effort, students’ advisors and members of Master’s thesis Committee / PhD Committee will be asked to provide related information online.

Specifically, (1) Master’s degree thesis-option students are required to complete a written self-reflection essay on entire MS program including thesis research and upload the final OGE approved thesis, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (2) Master’s degree non-thesis-option students are required to complete a written self-reflection essay on entire MS program and upload an assembled portfolio that includes reports from at least two course projects or homework from the core or depth courses, presentation slides from any course projects, along with the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (3) PhD students are required to complete a written self-reflection essay on entire PhD program including dissertation research and upload the final OGE approved dissertation, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation.

**Non-Thesis Option**
The non-thesis option is the more flexible of the two options. This program is designed with the working professional in mind. For this option, a grade of C- or better must be obtained in each course in order for that course to count toward the requirement of 45 QH. An overall minimum GPA of 3.0 is also required for graduation. Students may only take up to 8 quarter hours of independent study to be counted toward the degree, after approval by their advisor and the Chair. Each student must take a minimum of 24 quarter hours at the 4000-level.

**One Year (four quarters) – Non-thesis Option**
The Department of Electrical and Computer Engineering (ECE) offers a one-year, non-thesis option. Students who select the one-year program will be able to graduate within 12 months, four academic quarters, as there are enough courses offered in each specialization to meet the 20 QH depth requirement. The breadth requirement (14 QH) is fulfilled by taking courses offered in other specializations. In addition, every year courses that satisfy the mathematics requirement (3 QH) are offered. The MS non-thesis structure is shown below. QH in each category denote minimum requirements that must be satisfied. Any changes in the student’s plan of study must be approved a-prior by the student’s advisor.

The basic structure of the minimum 45 QH for the non-thesis option is as follows:

<table>
<thead>
<tr>
<th>Requirements for Non-Thesis Option (minimum QH)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate Assessment Requirement</td>
<td>0</td>
</tr>
<tr>
<td>Core Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Depth Requirement - Specialization Area</td>
<td>20</td>
</tr>
<tr>
<td>Mathematics Requirement (requires one approved course at the 3000-level or higher)</td>
<td>3</td>
</tr>
<tr>
<td>Breadth Requirement</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total Credits</strong></td>
<td><strong>45</strong></td>
</tr>
</tbody>
</table>

1 This indicates minimum number of quarter hours. Any credits over the required 3 QH from the mathematics courses will count toward the breadth requirement.

**Thesis Option**
A thesis permits a candidate to obtain depth in an area of study and it is especially useful for individuals who seek to pursue a subsequent degree, for example, a PhD degree. Thesis candidates work closely with a thesis advisor. The thesis option is required for all GRAs and GTAs. For this option, a grade of C- or better must be obtained in each course in order for that course to count toward the 45 QH hour requirements. An overall minimum
GPA of 3.0 is also required for graduation. Students may only take up to 8 quarter hours of independent study to be counted toward the degree. Each student must take a minimum of 16 quarter hours at the 4000-level. The basic structure of the minimum 45 QH for the thesis option is as follows:

### Requirements for Thesis Option (minimum QH)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Graduate Assessment Requirement</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Core Requirement</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Depth Requirement - Specialization Area</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Breadth Requirement $^1$</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Thesis</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Total Credits</td>
<td></td>
</tr>
</tbody>
</table>

$^1$ The breadth requirement must be pre-approved by the student's advisor.

If a student who has elected to pursue a thesis option, then at any time thereafter elects to change to a non-thesis option, all requirements for the non-thesis must be met. Any independent research taken may be forfeited and students must adhere to the grade requirements of the non-thesis option.

### Breadth Requirement (Non-Thesis and Thesis Option)

Breadth Requirement courses (each with not less than 3 QH of credit) may be chosen from courses offered in other specialization areas. A course that appears in more than one specialization area may only be counted toward either the specialization requirement or the breadth requirement. The remaining courses are chosen from appropriate courses numbered 3000 or higher, offered by the Department Mechanical & Materials Engineering, Department of Computer Science or NSM (Natural Sciences and Mathematics). Prior approval by the student's advisor is required. It is strongly recommended that students choose math related courses to satisfy the breadth requirement.

The MSEE program offers three areas of specialization:

- Control & Communication Systems
- Electric Power & Energy Systems
- Optics/Optoelectronics/Photonics

Each student must choose an area of specialization. The student's degree program will be a combination of the core courses, specialization areas (depth requirement) and the breadth requirement. Each student is required to complete the 2 core courses. Students may choose from any of the courses from their area of specialization but should keep in mind the 4000-level requirement of the degree.

### Core courses for all Electrical Engineering Students

The following courses are required for all electrical engineering students, regardless of area of specialization:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEE 4950</td>
<td>ECE Graduate Assessment</td>
<td>0</td>
</tr>
<tr>
<td>ENEE 4640</td>
<td>Electromagnetic Compatibility</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3621</td>
<td>Advanced Engineering Mathematics</td>
<td>4</td>
</tr>
</tbody>
</table>

### Specialization in Control & Communication Systems

This area of specialization prepares students for basic and applied research and development of complex systems, including, electrical, mechanical, bio-inspired, mechatronic systems, robotic systems, and unmanned systems. This is accomplished through several theoretical courses and applied courses. Students must choose from the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENCE 4231</td>
<td>Embedded Systems Programming</td>
<td>4</td>
</tr>
<tr>
<td>ENEE 3670</td>
<td>Introduction to Digital Signal Processing</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3721 &amp; ENGR 3722</td>
<td>Controls and Control Systems Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>ENEE 4141</td>
<td>Digital Communications</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4350</td>
<td>Reliability $^1$</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4620</td>
<td>Optimization $^1$</td>
<td>3,4</td>
</tr>
<tr>
<td>ENGR 4622</td>
<td>Advanced Optimization</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4730</td>
<td>Introduction to Robotics</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4735</td>
<td>Linear Systems</td>
<td>4</td>
</tr>
</tbody>
</table>
Specialization in Electric Power and Energy Systems
This area of specialization prepares students with the basic foundation and advanced knowledge, required for the research and development in the area of power systems, renewable energy systems, and power electronic devices. This is accomplished through several theoretical courses and applied courses. Students must choose from the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 3510</td>
<td>Renewable and Efficient Power and Energy Systems</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3540</td>
<td>Electric Power Systems</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3721</td>
<td>Controls</td>
<td>4</td>
</tr>
<tr>
<td>&amp; ENGR 3722</td>
<td>and Control Systems Laboratory</td>
<td></td>
</tr>
<tr>
<td>ENGR 4530</td>
<td>Intro to Power and Energy</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4545</td>
<td>Electric Power Economy</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4560</td>
<td>Power Generation Operation and Control</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4590</td>
<td>Power System Protection</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4735</td>
<td>Linear Systems</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4740</td>
<td>Adaptive Control Systems</td>
<td>4</td>
</tr>
</tbody>
</table>

Specialization in Optics/Optoelectronics/Photonics
This area of specialization prepares students for research, development, and design of devices and systems operating based on wave theory; focusing on laser, optics, light wave devices, and systems.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEE 4030</td>
<td>Optoelectronics</td>
<td>4</td>
</tr>
<tr>
<td>ENEE 4141</td>
<td>Digital Communications</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4200</td>
<td>Introduction to Nanotechnology</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4250</td>
<td>Advanced Hardware Description Language (HDL) Modeling and Synthesis</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4735</td>
<td>Linear Systems</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4740</td>
<td>Adaptive Control Systems</td>
<td>4</td>
</tr>
</tbody>
</table>

Master of Science in Mechatronic Systems Engineering
Minimum Credit Requirements
Every candidate for the MS degree must complete 45 QH of credit, at least 36 of which must be completed at the University of Denver.

Program Structure
Candidates may elect either the thesis or non-thesis option. This choice may be made at any time, although a delay in declaration may impact the completion date. Students who are GTAs or who receive financial support from a University research grant, such as GRAs, are required to elect the thesis option. The program is designed to be completed in about six quarters if two courses (usually 8 QH) are taken each quarter.

Required Graduate Assessment Course
ECE Graduate Assessment (ENEE 4950)
This graduate assessment course is required for all ECE graduate students to be taken in their last quarter (the term they have applied as the graduation term). All required assessment materials are uploaded to the course Assignments online 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. As part of the graduate assessment effort, students' advisors and members of Master's thesis Committee / PhD Committee will be asked to provide related information online. Specifically, (1) Master's degree thesis-option students are required to complete a written self-reflection essay on entire MS program including thesis research and upload the final OGE approved thesis, defense presentation slides, and the completed and signed degree program plan, by the published OGE "Deadline for thesis/dissertation formatting approval" of the students' last quarter before graduation. (2) Master's degree non-thesis-option students are required to complete a written self-reflection essay on entire MS program and upload an assembled portfolio that includes reports from
at least two course projects or homework from the core or depth courses, presentation slides from any course projects, along with the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation. (3) PhD students are required to complete a written self-reflection essay on entire PhD program including dissertation research and upload the final OGE approved dissertation, defense presentation slides, and the completed and signed degree program plan, by the published OGE “Deadline for thesis/dissertation formatting approval” of the students’ last quarter before graduation.

**Non-Thesis Option**

The non-thesis option is the more flexible of the two options. This program is designed with the working professional in mind. For this option, a grade of C- or better must be obtained in each course in order for that course to count toward the requirement of 45 QH. An overall minimum GPA of 3.0 is also required for graduation. Students may only take up to 8 quarter hours of independent study to be counted toward the degree, after approval by their advisor and the Chair. Each student must take a minimum of 24 quarter hours at the 4000-level.

**One Year (four quarters) – Non-thesis Option**

The Department of Electrical and Computer Engineering (ECE) offers a one-year, non-thesis option. Students who select the one-year program will be able to graduate within 12 months, four academic quarters, as there are enough courses offered in each specialization to meet the 20 QH depth requirement. The breadth requirement (14 QH) is fulfilled by taking courses offered in other specializations. In addition, every year courses that satisfy the mathematics requirement (3 QH) are offered. The MS non-thesis structure is shown below. QH in each category denote minimum requirements that must be satisfied. Any changes in the student’s plan of study must be approved a-priori by the student’s advisor.

The basic structure of the minimum 45 QH for the non-thesis option is as follows:

**Requirements for Non-Thesis Option (minimum quarter hours)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graduate Assessment Requirement</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Core Requirement</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Depth Requirement - Specialization Area</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Mathematics Requirement (requires one approved course at the 3000-level or higher)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Breadth Requirement</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><strong>Total Credits</strong></td>
<td>45</td>
</tr>
</tbody>
</table>

1. This indicates minimum number of quarter hours. Any credits over the required 3 QH from the mathematics courses will count toward the breadth requirement.

**Thesis Option**

A thesis permits a candidate to obtain depth in an area of study and it is especially useful for individuals who seek to pursue a subsequent degree, for example, a PhD degree. Thesis candidates work closely with a thesis advisor. The thesis option is required for all GRAs and GTAs. For this option, a grade of C- or better must be obtained in each course in order for that course to count toward the 45 QH hour requirements. An overall minimum GPA of 3.0 is also required for graduation. Students may only take up to 8 quarter hours of independent study to be counted toward the degree. Each student must take a minimum of 16 quarter hours at the 4000-level.

The basic structure of the minimum 45 QH for the thesis option is as follows:

**Requirements for Thesis Option (minimum quarter hours)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graduate Assessment Requirement</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Core Requirement</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Depth Requirement - Specialization Area</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Breadth Requirement 1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Thesis</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td><strong>Total Credits</strong></td>
<td>45</td>
</tr>
</tbody>
</table>

1. The breadth requirement must be pre-approved by the student’s advisor.

If a student who has elected to pursue a thesis option, then at any time thereafter elects to change to a non-thesis option, all requirements for the non-thesis must be met. Any independent research taken may be forfeited and students must adhere to the grade requirements of the non-thesis option.

**Breadth Requirement (Non-Thesis and Thesis Option)**

Breadth Requirement courses (each with not less than 3 QH of credit) may be chosen from courses offered in other specialization areas. A course that appears in more than one specialization area may only be counted toward either the specialization requirement or the breadth requirement. The remaining courses are chosen from appropriate courses numbered 3000 or higher, offered by the Department Mechanical & Materials Engineering, Department of Computer Science or NSM (Natural Sciences and Mathematics). Prior approval by the student’s advisor is required. It is strongly recommended that students choose math related courses to satisfy the breadth requirement.
The MSE program offers one area of specialization:

- Robotic Systems

The student's degree program will be a combination of the core courses, specialization areas (depth requirement) and the breadth requirement. Each student is required to complete the 2 core courses. Students may choose from any of the courses from their area of specialization but should keep in mind the 4000-level requirement of the degree.

Core courses for all Mechatronic Systems Engineering Students

The following courses are required for all mechatronic systems engineering students regardless of area of specialization:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEE 4950</td>
<td>ECE Graduate Assessment</td>
<td>0</td>
</tr>
<tr>
<td>ENEE 4640</td>
<td>Electromagnetic Compatibility</td>
<td>4</td>
</tr>
<tr>
<td>or ENCE 4110</td>
<td>Modern Digital Systems Design</td>
<td></td>
</tr>
<tr>
<td>ENGR 3621</td>
<td>Advanced Engineering Mathematics</td>
<td>4</td>
</tr>
</tbody>
</table>

Specialization in Robotics Systems

This area of specialization is designed to meet the needs of industry and federal research laboratories for engineers with multidisciplinary experience and ability to design and integrate complex systems requiring knowledge from diverse engineering disciplines. Said differently, mechatronic systems involves integration of mechanical, electrical, and computer engineering to design complex systems that perform real-world tasks. This program includes a broad set of common course requirements along with a selection of appropriate technical electives providing both breadth and depth of knowledge in a student's area of interest.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENCE 4231</td>
<td>Embedded Systems Programming</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4250</td>
<td>Advanced Hardware Description Language (HDL) Modeling and Synthesis</td>
<td>4</td>
</tr>
<tr>
<td>ENCE 4620</td>
<td>Advanced Computer Vision</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 3630</td>
<td>Finite Element Methods ¹</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4620</td>
<td>Optimization ¹</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4730</td>
<td>Introduction to Robotics</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4735</td>
<td>Linear Systems</td>
<td>4</td>
</tr>
<tr>
<td>ENME 4020</td>
<td>Adv Finite Element Analysis ¹</td>
<td>4</td>
</tr>
<tr>
<td>ENMT 4220</td>
<td>Mechatronics II</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4740</td>
<td>Adaptive Control Systems</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 4745</td>
<td>Adv Non-Linear Control System</td>
<td>4</td>
</tr>
</tbody>
</table>

¹ This course may count toward the specialization with advisors preapproval. This course may not or may not be offered on a regular basis.

Master of Science in Systems Engineering (Online)

Minimum of 45 credit hours are required for the degree.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSY 4010</td>
<td>Systems Engineering Fundamentals</td>
<td></td>
</tr>
<tr>
<td>ENSY 4050</td>
<td>Digital Transformation for Advanced Integration</td>
<td></td>
</tr>
<tr>
<td>ENSY 4090</td>
<td>Project Management in Relation to Systems Engineering</td>
<td></td>
</tr>
<tr>
<td>ENMT 4000</td>
<td>Space Systems Design I ²</td>
<td></td>
</tr>
<tr>
<td>ENMT 4010</td>
<td>Space Systems Design II ²</td>
<td></td>
</tr>
<tr>
<td>ENSY 4021</td>
<td>Design of Space Systems Part 1</td>
<td></td>
</tr>
<tr>
<td>ENSY 4022</td>
<td>Design of Space Systems Part 2</td>
<td></td>
</tr>
<tr>
<td>ENSY 4040</td>
<td>Systems Optimization</td>
<td></td>
</tr>
</tbody>
</table>
Specialized Graduate Certificate in The Systems Design and Architecture

Required Courses

- ENSY 4012 Systems Engineering Requirements Development
- ENSY 4014 Complex System Architectures
- ENSY 4016 Conceptual Design of Systems

Required Elective Courses (Choose at least two courses totaling 6 credit hours)

- ENSY 4024 Applied Electrical, Mechanical and Software Systems
- ENSY 4030 Introduction to Aerospace Missions
- ENSY 4040 Systems Optimization
- ENSY 4060 Practical Model Based Systems Engineering
- ENSY 4112 Practical Validation and Verification Test Planning
- ENGR 4501 Graduate Capstone Design I
- ENGR 4502 Graduate Capstone Design II
- ENGR 4503 Graduate Capstone Design III
- ENGR 4504 Graduate Capstone Design IV
- ENGR 4991 Independent Study

Specialized Graduate Certificate in The Systems Analytics & Practice

Required Courses

- ENSY 4180 Applied Mathematics for Systems Engineering
- ENSY 4181 Introductory Probability and Statistics for Systems Engineering
- ENSY 4182 Data Analytics for Systems Engineering

Required Elective Courses (Choose two courses totaling at least 6 credit hours)

- ENSY 4042 Optimization for Advanced Systems
- ENSY 4112 Practical Validation and Verification Test Planning
- ENSY 4170 Practical Approaches to Continuous Improvement
- ENSY 4200 Applied Machine Learning for Advanced Systems Modeling
- ENGR 4501 Graduate Capstone Design I
- ENGR 4502 Graduate Capstone Design II
- ENGR 4503 Graduate Capstone Design III
- ENGR 4504 Graduate Capstone Design IV
- ENGR 4991 Independent Study

1 A maximum of 9 credit hours of the Graduate Capstone Design series will be applied as Required Elective Credit. Only Lockheed Martin employees in the Engineering Leadership Development Program (ELDP) may take the Graduate Capstone Design series courses.

2 These courses are only available to Lockheed Martin Employees at this time.

Specialized Graduate Certificate Programs

Specialized Graduate Certificate in the Fundamentals of Systems Engineering

This Specialized Graduate Certificate provides expertise in fundamentals of the discipline of systems engineering, applicable to engineering professionals in many industries, particularly regulated industries such as aerospace, biomedical, and autonomous vehicles.

Please note that this is the first of the three stackable certificates leading to the MS in Systems Engineering (Online) and is available as a singular Specialized Graduate Certificate.

Minimum Credit Requirements

Every candidate for the Specialized Graduate Certificate must complete 15 credit hours.
### Required Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSY 4010</td>
<td>Systems Engineering Fundamentals</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4050</td>
<td>Digital Transformation for Advanced Integration</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4090</td>
<td>Project Management in Relation to Systems Engineering</td>
<td>3</td>
</tr>
</tbody>
</table>

### Required Elective Courses (Choose at least two courses totaling 6 credit hours)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSY 4021</td>
<td>Design of Space Systems Part 1</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4022</td>
<td>Design of Space Systems Part 2</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4040</td>
<td>Systems Optimization</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4060</td>
<td>Practical Model Based Systems Engineering</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 4501</td>
<td>Graduate Capstone Design I</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 4502</td>
<td>Graduate Capstone Design II</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 4503</td>
<td>Graduate Capstone Design III</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 4504</td>
<td>Graduate Capstone Design IV</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 4991</td>
<td>Independent Study</td>
<td>1-5</td>
</tr>
</tbody>
</table>

**Total Credits**: 15

### Specialized Graduate Certificate in Systems Analytics & Practice

This Specialized Graduate Certificate provides systems engineering expertise with practical exposure to the analytical and digital tools which are paramount to the evolving practice of systems engineering. This practical exposure is designed to enable the student to participate in rigorous post-test data analysis, to participate in model based design and model based systems engineering, as well as statistically relevant process improvement projects. Case studies are applicable to engineering professionals in many industries, particularly regulated industries such as aerospace, biomedical, and autonomous vehicles.

Please note that this is the third of the three stackable certificates leading to the MS in Systems Engineering (Online) and is available as a singular Specialized Graduate Certificate.

**Minimum Credit Requirements**

Every candidate for the Specialized Graduate Certificate must complete 15 credit hours.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSY 4180</td>
<td>Applied Mathematics for Systems Engineering</td>
<td></td>
</tr>
<tr>
<td>ENSY 4181</td>
<td>Introductory Probability and Statistics for Systems Engineering</td>
<td></td>
</tr>
<tr>
<td>ENSY 4182</td>
<td>Data Analytics for Systems Engineering</td>
<td></td>
</tr>
</tbody>
</table>

### Required Elective Courses (Choose two courses totaling at least 6 credit hours)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSY 4042</td>
<td>Optimization for Advanced Systems</td>
<td></td>
</tr>
<tr>
<td>ENSY 4112</td>
<td>Practical Validation and Verification Test Planning</td>
<td></td>
</tr>
<tr>
<td>ENSY 4170</td>
<td>Practical Approaches to Continuous Improvement</td>
<td></td>
</tr>
<tr>
<td>ENSY 4200</td>
<td>Applied Machine Learning for Advanced Systems Modeling</td>
<td></td>
</tr>
<tr>
<td>ENGR 4501</td>
<td>Graduate Capstone Design I</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 4502</td>
<td>Graduate Capstone Design II</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 4503</td>
<td>Graduate Capstone Design III</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 4504</td>
<td>Graduate Capstone Design IV</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 4991</td>
<td>Independent Study</td>
<td></td>
</tr>
</tbody>
</table>

**Total Credits**: 15

A maximum of 9 credit hours of Graduate Capstone Design courses will be applied as Required Elective Credit. Only Lockheed Martin employees in the current ELDP cohort may take the Graduate Capstone Design series courses.
Specialized Graduate Certificate in Systems Design and Architecture

This Specialized Graduate Certificate provides systems engineering expertise with emphasis on support for proposals after contract award, through critical design reviews, as well as system design and integration and associated validation and verification activities, which are necessarily traceable to system requirements. Case studies are applicable to engineering professionals in many industries, particularly regulated industries such as aerospace, biomedical, and autonomous vehicles.

Please note that this is the second of the three stackable certificates leading to the MS in Systems Engineering (Online) and is available as a singular Specialized Graduate Certificate.

Minimum Credit Requirements

Every candidate for the Specialized Graduate Certificate must complete 15 credit hours.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSY 4012</td>
<td>Systems Engineering Requirements Development</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4014</td>
<td>Complex System Architectures</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4016</td>
<td>Conceptual Design of Systems</td>
<td>3</td>
</tr>
<tr>
<td>ENSY 4024</td>
<td>Applied Electrical, Mechanical and Software Systems</td>
<td></td>
</tr>
<tr>
<td>ENSY 4030</td>
<td>Introduction to Aerospace Missions</td>
<td></td>
</tr>
<tr>
<td>ENSY 4040</td>
<td>Systems Optimization</td>
<td></td>
</tr>
<tr>
<td>ENSY 4060</td>
<td>Practical Model Based Systems Engineering</td>
<td></td>
</tr>
<tr>
<td>ENSY 4112</td>
<td>Practical Validation and Verification Test Planning</td>
<td></td>
</tr>
<tr>
<td>ENGR 4501</td>
<td>Graduate Capstone Design I</td>
<td></td>
</tr>
<tr>
<td>ENGR 4502</td>
<td>Graduate Capstone Design II</td>
<td></td>
</tr>
<tr>
<td>ENGR 4503</td>
<td>Graduate Capstone Design III</td>
<td></td>
</tr>
<tr>
<td>ENGR 4504</td>
<td>Graduate Capstone Design IV</td>
<td></td>
</tr>
<tr>
<td>ENGR 4991</td>
<td>Independent Study</td>
<td></td>
</tr>
</tbody>
</table>

Total Credits 15

1 A maximum of 9 credit hours of Graduate Capstone Design courses will be applied as Required Elective Credit. Only Lockheed Martin employees in the current ELDP cohort may take the Graduate Capstone Design series courses.

Engineering, Computer (ENCE)

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 3632 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)
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 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)

Engineering, Electrical (ENEE)

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 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 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 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 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 Compatiblity (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 5995 PhD Independent Research (1-10 Credits)
ENEE 6991 Ph.D Independent Study (1-10 Credits)
ENEE 6995 Independent Research (1-16 Credits)

Engineering, Systems (ENSY)

ENSY 4010 Systems Engineering Fundamentals (3 Credits)
An overview of systems engineering, including V-diagrams, functional architecture, physical architecture, system assembly and integration, verification and validation, and milestones to monitor the progress of the design.

ENSY 4012 Systems Engineering Requirements Development (3 Credits)
The course covers fundamentals of design and requirements analysis of complex systems to meet overall mission requirements. Spanning the requirements engineering phase, topics include: decomposition, derivation, allocation, verification and validation planning. Prerequisite: ENSY 4010, or permission of instructor.
ENSY 4014 Complex System Architectures (3 Credits)
The course focuses on mission requirements and how an overall mission should function by examining different architecture configurations and tools for modeling purposes. Topics include: allocation of functional and non-functional requirements, Service Oriented Architecture (SOA) and architectural modeling using the System Modeling Language (SysML). Prerequisite: ENSY 4010.

ENSY 4016 Conceptual Design of Systems (3 Credits)
Conceptual design is the part of the design process that yields a basic solution path, which leads to the principle solution. The focus of the course is on two important decision making principles: understanding a problem and devising a plan. Topics include: intellectual property and the development of engineering drawings, schematics and 3D models.

ENSY 4021 Design of Space Systems Part 1 (3 Credits)
This course is part one of a two-part series on spacecraft design by integrated systems and subsystems. Topics include: spacecraft overview, subsystem interfaces, concepts of operation (CONOPS) and the systems engineer's role as a generalist as opposed to specialists.

ENSY 4022 Design of Space Systems Part 2 (3 Credits)
This course is part two of a two-part series on spacecraft design by integrated systems and subsystems. Topics correspond to decomposition of the spacecraft into classical spacecraft subsystems. Practical applications and core functionality of these subsystems are presented, including required testing and integration at the subsystem and spacecraft levels. Prerequisite: ENSY 4021.

ENSY 4024 Applied Electrical, Mechanical and Software Systems (3 Credits)
This is a practice-centered course. Assess case studies of design, implementation and testing, validation and verification of complete complex (e.g. spacecraft) systems to meet mission requirements with performance guarantees. Prerequisites: ENSY 4012, ENSY 4014, and ENSY 4016, or permission by the Instructor.

ENSY 4030 Introduction to Aerospace Missions (3 Credits)
This class is for individuals working in aerospace engineering and related fields. Topics include: 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).

ENSY 4040 Systems Optimization (3 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. Assignments are in context of Systems Engineering case studies.

ENSY 4042 Optimization for Advanced Systems (3 Credits)
Advanced optimization algorithms are presented, as a pillar of data science and machine learning. Topics include: linear, nonlinear and integer programming models. Students will learn to understand tractability of models, particularly complex models as are central to the discipline of Systems Engineering. Prerequisite: ENSY 4040.

ENSY 4050 Digital Transformation for Advanced Integration (3 Credits)
Digital engineering technologies address the difficulties of managing complex and evolving technologies over their lifecycles of (i) development and (ii) operations & maintenance. This course will focus on digital technologies to integrate data across the enterprise, break organizational silos, and drive culture to realize risk reduction. Topics include: elements of the digital thread, such as digital twins and simulation, as well as machine learning and data analytics to inform decision-making throughout the lifecycle.

ENSY 4060 Practical Model Based Systems Engineering (3 Credits)
MBSE is part of a long-term trend toward model-centric approaches adopted by other engineering disciplines, including mechanical, electrical and software. In this course, students will be given hands-on access to MBSE tools in order to learn the UML/SysML language of MBSE and to practice systems engineering methods using the digital thread that is enabled by MBSE. Students will also gain an understanding of MBSE being a subset of Model Based Design (MBD). Prerequisite: ENSY 4050, or permission of instructor.

ENSY 4090 Project Management in Relation to Systems Engineering (3 Credits)
An overview of the skills and strategies for managing people, risks, schedules, and information to meet goals and objectives in large, complicated engineering projects. Includes managing project constraints, and best practices for working with project managers. Emphasis is on People, Process and the Business Environment.

ENSY 4112 Practical Validation and Verification Test Planning (3 Credits)
In this course, students gain a practical understanding of V-diagrams, and the path that must be traveled to fully validate and verify any system. Topics include: traceability between requirements and validation and verification test plans, including practical development of detailed test procedures at any level of integration. Prerequisite ENSY 4012, or permission by the instructor.

ENSY 4170 Practical Approaches to Continuous Improvement (3 Credits)
In this course, students learn practical differences between Continuous Improvement (CI) methods, such as Kaizen, Lean, Six Sigma, and Total Quality Management (TQM). Current events will be used as case studies to apply practical understanding of these CI methods. Practical application of the methods will leverage principles taught in ENSY 4010, ENSY 4071 and ENSY 4072. Case studies and assignments are based on illustrations of value added CI engineering in the Systems Engineering discipline. Prerequisites: ENSY 4010, ENSY 4071 and ENSY 4072; or instructor approval.
**ENSY 4180 Applied Mathematics for Systems Engineering (3 Credits)**
The course reviews topics in continuous and discrete mathematics (integral and differential calculus, matrices, vector calculus, discrete math: matrices, graphs, sets) and introductory probability, as they apply to engineering, and introduces students to more advanced concepts aiding the understanding and design of complex engineering systems. Examples are drawn from engineering systems applications. Students apply the techniques using engineering computing platform.

**ENSY 4181 Introductory Probability and Statistics for Systems Engineering (3 Credits)**
This course introduces fundamentals of probability for Systems Engineers. Students survey data visualization methods and summary statistics, develop models for data, and apply statistical techniques to assess the validity of the models. Techniques include parametric and nonparametric methods for parameter estimation and hypothesis testing for a single sample mean and two sample means, for proportions, and for simple linear regression. Students will apply methods to real-world engineering data, primarily using R.

**ENSY 4182 Data Analytics for Systems Engineering (3 Credits)**
This course is designed for students to develop skills in data analytics specifically tailored for systems engineering applications. It combines theoretical understanding with practical applications, covering various models for data inference, statistical methodologies, and the use of data analytics tools and software.

**ENSY 4200 Applied Machine Learning for Advanced Systems Modeling (3 Credits)**
This course covers topics in Machine Learning including Bayesian decision theory, supervised learning, unsupervised learning and clustering, linear discriminant functions, linear classification techniques such as Support Vector Machines, as well as Artificial Neural Networks and Deep Learning methods.

**ENSY 4950 Graduate Assessment for Master of Science degree in Systems Engineering (0 Credits)**
This class does not meet. All MS in Systems Engineering (MSSY) graduate students will enroll in this class during their last quarter. The purpose is to collect data for the assessment and continuous improvement of the graduate programs. 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.

### Engineering, Computer Courses

**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 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 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: ENSE 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 include 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 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)

Engineering, Electrical Courses

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 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 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 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 4620. 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 5995 PhD Independent Research (1-10 Credits)
ENEE 6991 Ph.D Independent Study (1-10 Credits)
ENEE 6995 Independent Research (1-16 Credits)

Engineering, Systems Courses

ENSY 4010 Systems Engineering Fundamentals (3 Credits)
An overview of systems engineering, including V-diagrams, functional architecture, physical architecture, system assembly and integration, verification and validation, and milestones to monitor the progress of the design.

ENSY 4012 Systems Engineering Requirements Development (3 Credits)
The course covers fundamentals of design and requirements analysis of complex systems to meet overall mission requirements. Spanning the requirements engineering phase, topics include: decomposition, derivation, allocation, verification and validation planning. Prerequisite: ENSY 4010, or permission of instructor.

ENSY 4014 Complex System Architectures (3 Credits)
The course focuses on mission requirements and how an overall mission should function by examining different architecture configurations and tools for modeling purposes. Topics include: allocation of functional and non-functional requirements, Service Oriented Architecture (SOA) and architectural modeling using the System Modeling Language (SysML). Prerequisite: ENSY 4010.

ENSY 4016 Conceptual Design of Systems (3 Credits)
Conceptual design is the part of the design process that yields a basic solution path, which leads to the principle solution. The focus of the course is on two important decision making principles: understanding a problem and devising a plan. Topics include: intellectual property and the development of engineering drawings, schematics and 3D models.

ENSY 4021 Design of Space Systems Part 1 (3 Credits)
This course is part one of a two-part series on spacecraft design by integrated systems and subsystems. Topics include: spacecraft overview, subsystem interfaces, concepts of operation (CONOPS) and the systems engineer’s role as a generalist as opposed to specialists.

ENSY 4022 Design of Space Systems Part 2 (3 Credits)
This course is part two of a two-part series on spacecraft design by integrated systems and subsystems. Topics correspond to decomposition of the spacecraft into classical spacecraft subsystems. Practical applications and core functionality of these subsystems are presented, including required testing and integration at the subsystem and spacecraft levels. Prerequisite: ENSY 4021.

ENSY 4024 Applied Electrical, Mechanical and Software Systems (3 Credits)
This is a practice-centered course. Assess case studies of design, implementation and testing, validation and verification of complete complex (e.g. spacecraft) systems to meet mission requirements with performance guarantees. Prerequisites: ENSY 4012, ENSY 4014, and ENSY 4016, or permission by the Instructor.

ENSY 4030 Introduction to Aerospace Missions (3 Credits)
This class is for individuals working in aerospace engineering and related fields. Topics include: 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).

ENSY 4040 Systems Optimization (3 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. Assignments are in context of Systems Engineering case studies.

ENSY 4042 Optimization for Advanced Systems (3 Credits)
Advanced optimization algorithms are presented, as a pillar of data science and machine learning. Topics include: linear, nonlinear and integer programming models. Students will learn to understand tractability of models, particularly complex models as are central to the discipline of Systems Engineering. Prerequisite: ENSY 4040.

ENSY 4050 Digital Transformation for Advanced Integration (3 Credits)
Digital engineering technologies address the difficulties of managing complex and evolving technologies over their lifecycles of (i) development and (ii) operations & maintenance. This course will focus on digital technologies to integrate data across the enterprise, break organizational silos, and drive culture to realize risk reduction. Topics include: elements of the digital thread, such as digital twins and simulation, as well as machine learning and data analytics to inform decision-making throughout the lifecycle.

ENSY 4060 Practical Model Based Systems Engineering (3 Credits)
MBSE is part of a long-term trend toward model-centric approaches adopted by other engineering disciplines, including mechanical, electrical and software. In this course, students will be given hands-on access to MBSE tools in order to learn the UML/SysML language of MBSE and to practice systems engineering methods using the digital thread that is enabled by MBSE. Students will also gain an understanding of MBSE being a subset of Model Based Design (MBD). Prerequisite: ENSY 4050, or permission of instructor.
ENSY 4090 Project Management in Relation to Systems Engineering (3 Credits)
An overview of the skills and strategies for managing people, risks, schedules, and information to meet goals and objectives in large, complicated engineering projects. Includes managing project constraints, and best practices for working with project managers. Emphasis is on People, Process and the Business Environment.

ENSY 4112 Practical Validation and Verification Test Planning (3 Credits)
In this course, students gain a practical understanding of V-diagrams, and the path that must be traveled to fully validate and verify any system. Topics include: traceability between requirements and validation and verification test plans, including practical development of detailed test procedures at any level of integration. Prerequisite ENSY 4012, or permission by the instructor.

ENSY 4170 Practical Approaches to Continuous Improvement (3 Credits)
In this course, students learn practical differences between Continuous Improvement (CI) methods, such as Kaizen, Lean, Six Sigma, and Total Quality Management (TQM). Current events will be used as case studies to apply practical understanding of these CI methods. Practical application of the methods will leverage principles taught in ENSY 4010, ENSY 4071 and ENSY 4072. Case studies and assignments are based on illustrations of value added CI engineering in the Systems Engineering discipline. Prerequisites: ENSY 4010, ENSY 4071 and ENSY 4072; or instructor approval.

ENSY 4180 Applied Mathematics for Systems Engineering (3 Credits)
The course reviews topics in continuous and discrete mathematics (integral and differential calculus, matrices, vector calculus, discrete math: matrices, graphs, sets) and introductory probability, as they apply to engineering, and introduces students to more advanced concepts aiding the understanding and design of complex engineering systems. Examples are drawn from engineering systems applications. Students apply the techniques using engineering computing platform.

ENSY 4181 Introductory Probability and Statistics for Systems Engineering (3 Credits)
This course introduces fundamentals of probability for Systems Engineers. Students survey data visualization methods and summary statistics, develop models for data, and apply statistical techniques to assess the validity of the models. Techniques include parametric and nonparametric methods for parameter estimation and hypothesis testing for a single sample mean and two sample means, for proportions, and for simple linear regression. Students will apply methods to real-world engineering data, primarily using R.

ENSY 4182 Data Analytics for Systems Engineering (3 Credits)
This course is designed for students to develop skills in data analytics specifically tailored for systems engineering applications. It combines theoretical understanding with practical applications, covering various models for data inference, statistical methodologies, and the use of data analytics tools and software.

ENSY 4200 Applied Machine Learning for Advanced Systems Modeling (3 Credits)
This course covers topics in Machine Learning including Bayesian decision theory, supervised learning, unsupervised learning and clustering, linear discriminant functions, linear classification techniques such as Support Vector Machines, as well as Artificial Neural Networks and Deep Learning methods.

ENSY 4950 Graduate Assessment for Master of Science degree in Systems Engineering (0 Credits)
This class does not meet. All MS in Systems Engineering (MSSY) graduate students will enroll in this class during their last quarter. The purpose is to collect data for the assessment and continuous improvement of the graduate programs. 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.