DEPARTMENT OF ELECTRICAL ENGINEERING

The Department of Electrical Engineering offers a Doctor of Philosophy degree in Electrical Engineering, a Master of Science degree in Electrical Engineering, a Master of Science degree in Advanced Materials Engineering, and an Integrated Bachelor of Science/Master of Science program in Electrical Engineering. It also offers a Graduate Certificate in Cloud Computing.

Master of Science Degree in Advanced Materials Engineering

The Master of Science (M.S.) degree in Advanced Materials Engineering (MatE) at The University of Texas at San Antonio is an interdisciplinary graduate degree program offered by the Klesse College of Engineering and Integrated Design. The M.S. in MatE degree program is directed by the Advanced Materials Engineering Graduate Program Committee and is currently administered by the Department of Electrical Engineering.

The Master of Science degree in Advanced Materials Engineering is designed to offer training opportunities for graduate students to gain the state-of-the-art technical knowledge and skill sets necessary for independent critical thinking, problem solving, and decision making to address multidisciplinary problems in materials engineering. The degree program also provides students with opportunities for taking multidisciplinary courses from the Klesse College of Engineering and Integrated Design and other colleges at UT San Antonio to enhance students' interdisciplinary research potentials, as well as their technical leadership and entrepreneurship skills. The affiliated program faculty consists of UT San Antonio graduate faculty who offer MatE core/concentration courses or serve on MatE Program/Supervising Committees during the current or previous catalog period. Each MatE program faculty member is actively engaged in interdisciplinary research/education and brings to this program an extensive and wide range of expertise.

The program addresses three interlinked areas of knowledge in advanced materials engineering:

1. Structure-function relationships in materials, which determine behavior at the macro-, micro-, nano-, molecular-, and atomic-levels;
2. Synthesis, characterization, measurement, and computational modeling of materials (ceramics, composites, metals, polymers, multifunctional, electronic, and biomedical), especially those with novel multifunctional properties; and
3. Design and fabrication of advanced materials and devices that address current and future technological challenges in a wide range of applications, including energy, communications, control and automation, health and medicine, nanotechnology, structural and environmental, and transportation.

The M.S. in MatE offers core courses to all enrolled students to achieve a common platform of understanding and knowledge. Subsequently, students will choose their concentrations according to materials classifications and applications. Currently three concentrations are offered:

- Concentration I – Multifunctional Electronic, Dielectric, Photonic, and Magnetic Materials
- Concentration II – Multifunctional Biomedical Materials
- Concentration III – Semiconductor Materials and Manufacturing

Upon recommendation of the student's Supervising Professor and with the approval of the Program Director, a student may take graduate-level courses offered by other graduate programs related to materials science and engineering, including select Management of Technology courses from College of Business, to augment the student's education and creativity in interdisciplinary areas and to better prepare the student for jobs in research and in the industry.

Both thesis and non-thesis options are available.

Program Admission Requirements

In addition to the University-wide graduate admission requirements, admission decisions will be made by the Admissions Committee based on a combination of the following:

- A bachelor's degree in any discipline of engineering or sciences, especially from materials science, physics, or chemistry. A minimum grade point average of 3.0 (on a 4.0 scale) in the last 60 semester credit hours of undergraduate studies.
- A statement of research experience, interests and goals.
- 1 to 2 letter(s) of recommendation.
- Students whose native language is not English must achieve a minimum score of 79 on the Test of English as a Foreign Language (TOEFL) iBT, or 6.5 on the International English Language Testing System (IELTS).
- Submission of the Graduate Record Examination (GRE) is optional but recommended for consideration of competitive scholarships.

Degree Requirements

The minimum number of semester credit hours required for the M.S. in MatE degree is 30 for the thesis option and 33 for the non-thesis option.

Thesis Option

The degree requires 30 semester credit hours, including 24 technical course credits and 6 thesis credits identified as MATE 6983 Master's Thesis Research. A total of 18 semester credit hours, including 9 credits of core courses in Group A and 9 credits of courses (at least 6 credits from the chosen concentration) in Group B, must be taken to satisfy the depth and the breadth requirements. Up to 6 credits may be taken from courses in Group C, including courses from outside of the Klesse College of Engineering and Integrated Design, with the approval of the Advanced Materials Engineering Graduate Program Committee. A current list of MATE graduate courses is available in the department office. No more than a total of 3 semester credit hours of MATE 6951, MATE 6952, or MATE 6953 Directed Research in Advanced Materials Engineering; MOT 6971 or MOT 6973 Special Problems; and Research Seminar (BME 6011 or EE 6991) may be included.

Course listings of Group A, B, and C are common for both Thesis and Non-Thesis options.

Code	Title	Credit Hours
A. Required Core Courses from Group A		**9**
Group A. Required core courses:		
MATE 5103	Principles of Materials Engineering: Fundamentals of Structure, Chemistry, and Physical Properties	
or EE 5693	Dielectric and Optoelectronic Devices	
MATE 5113	Functions, Evaluations and Synthesis Technology of Advanced Materials	
MOT 5163	Management of Technology	
B. Concentration specific courses from Group B		**9**
Group B. Concentration-specific courses; at least 6 credits must be from the chosen concentration:		
Concentration I: Multifunctional Electronic, Dielectric, Photonic, and Magnetic Materials		
EE 5403	Advanced Dielectric and Optoelectronic Engineering Laboratory	
EE 5503	Introduction to Nanoelectronics	
EE 5693	Dielectric and Optoelectronic Devices	
or MATE 5103	Principles of Materials Engineering: Fundamentals of Structure, Chemistry, and Physical Properties	
EE 6493	Advanced Topics in Electronic Materials and Devices	
MATE 5213	Sensing and Sensor Materials	
MATE 5223	Structure-Chemistry-Property Relations in Materials Science and Engineering	
MATE 5233	Anisotropy and Crystalline Materials	
MATE 5243	Optic and Nonlinear Optical Materials	
MATE 5253	Magnetic Materials and Electromagnetic Engineering	
MATE 5393	Topics in Advanced Materials Engineering	
MATE 5493	Topics in Materials Engineering and Application	
Concentration II: Multifunctional Biomedical Materials		
BME 6093	Topics in Biomedical Engineering	
BME 6743	Biophotonics	
BME 6903	Biomaterials	
BME 6933	Tissue-Biomaterials Interactions	
BME 6963	Fundamentals to Polymer Science with Select Biomedical Applications	
MATE 5513	Fundamentals of Microfabrication and Application	
or BME 6733	Microfabrication and Application	
MATE 5523	Biosensors: Fundamentals and Applications	
or BME 6753	Biosensors: Fundamentals and Applications	
BME 6803	Experimental Biomechanics	
MATE 5543	Current Analytical Tools for Biomaterials Characterizations	
MATE 5393	Topics in Advanced Materials Engineering	
MATE 5493	Topics in Materials Engineering and Application	
Concentration III: Semiconductor Materials and Manufacturing		
EE 5113	VLSI System Design	
EE 5293	Topics in Microelectronics	
EE 5403	Advanced Dielectric and Optoelectronic Engineering Laboratory	
EE 5503	Introduction to Nanoelectronics	
MATE 5513	Fundamentals of Microfabrication and Application	
or EE 5413	Principles of Microfabrication	
PHY 7503	Topics in Experimental Physics (Electron Microscopy)	
PHY 7973	Special Topics in Physics (Semiconductor Device Physics)	
PHY 7973	Special Topics in Physics (Advanced Materials Characterizations)	
PHY 7973	Special Topics in Physics (Quantum Electronic Physics)	
MATE 5393	Topics in Advanced Materials Engineering	
MATE 5493	Topics in Materials Engineering and Application	
C. Prescribed Electives from Group C		**6**
Group C. Prescribed elective courses. Additional elective courses may be added with approval of the Advanced Materials Engineering Graduate Program Committee.		
CHE 5263	Advanced Analytical Chemistry	
BME 6011	Research Seminar	
BME 6723	Bioinstrumentations	
BME 6943	Biomaterials and Cell Signaling	
EE 5293	Topics in Microelectronics	
EE 6991	Research Seminar	
MATE 6951	Directed Research in Advanced Materials Engineering	
MATE 6952	Directed Research in Advanced Materials Engineering	
MATE 6953	Directed Research in Advanced Materials Engineering	
ME 5483	Finite Element Methods	
ME 5713	Mechanical Behavior of Materials	
ME 5743	Composite Materials	
ME 6013	Advanced Engineering Mathematics I	
MOT 5243	Essentials of Project Management	
MOT 5253	Starting the High-Tech Firm	
MOT 5313	Emerging Technologies	
MOT 5333	Technological Drivers of Globalization	
PHY 5303	Statistical Mechanics	
PHY 7503	Topics in Experimental Physics	
D. Master's Thesis (a minimum of 6 semester credit hours)		**6**
MATE 6983	Master's Thesis Research	
Total Credit Hours		**30**

Non-Thesis Option

The degree requires 33 semester credit hours, including 30 technical course credits and 3 project credits identified as MATE 6943 Master's Project. A total of 24 semester credit hours, including 9 credits of core courses in Group A and 12 credits of courses (at least 9 credits from the chosen concentration) in Group B must be taken to satisfy the

depth and the breadth requirements. Up to 9 credits may be taken from courses in Group C, including courses from out of the Klesse College of Engineering and Integrated Design, with the approval of the Advanced Materials Engineering Graduate Program Committee. A current list of MATE graduate courses is available in the department office. No more than a total of 3 semester credit hours of MATE 6951, MATE 6952, or MATE 6953 Directed Research in Advanced Materials Engineering; MOT 6971 or MOT 6973 Special Problems; and Research Seminar (BME 6011 or EE 6991) may be included.

Course listings of Group A, B, and C are common for both Thesis and Non-Thesis options.

Code	Title	Credit Hours
A. Required Core Courses from Group A		**9**
Group A. Required core courses:		
MATE 5103	Principles of Materials Engineering: Fundamentals of Structure, Chemistry, and Physical Properties	
or EE 5693	Dielectric and Optoelectronic Devices	
MATE 5113	Functions, Evaluations and Synthesis Technology of Advanced Materials	
MOT 5163	Management of Technology	
B. Concentration-specific courses from Group B		**12**
Group B. Concentration specific courses; at least 9 credits must be from the chosen concentration		
Concentration I: Multifunctional Electronic, Dielectric, Photonic, and Magnetic Materials		
EE 5403	Advanced Dielectric and Optoelectronic Engineering Laboratory	
EE 5503	Introduction to Nanoelectronics	
EE 5693	Dielectric and Optoelectronic Devices	
or MATE 5103	Principles of Materials Engineering: Fundamentals of Structure, Chemistry, and Physical Properties	
EE 6493	Advanced Topics in Electronic Materials and Devices	
MATE 5213	Sensing and Sensor Materials	
MATE 5223	Structure-Chemistry-Property Relations in Materials Science and Engineering	
MATE 5233	Anisotropy and Crystalline Materials	
MATE 5243	Optic and Nonlinear Optical Materials	
MATE 5253	Magnetic Materials and Electromagnetic Engineering	
MATE 5393	Topics in Advanced Materials Engineering	
MATE 5493	Topics in Materials Engineering and Application	
Concentration II: Multifunctional Biomedical Materials		
BME 6093	Topics in Biomedical Engineering	
BME 6743	Biophotonics	
BME 6903	Biomaterials	
BME 6933	Tissue-Biomaterials Interactions	
BME 6963	Fundamentals to Polymer Science with Select Biomedical Applications	
BME 6803	Experimental Biomechanics	
MATE 5513	Fundamentals of Microfabrication and Application	
or BME 6733	Microfabrication and Application	
MATE 5523	Biosensors: Fundamentals and Applications	
or BME 6753	Biosensors: Fundamentals and Applications	
MATE 5543	Current Analytical Tools for Biomaterials Characterizations	
MATE 5393	Topics in Advanced Materials Engineering	
MATE 5493	Topics in Materials Engineering and Application	
Concentration III: Semiconductor Materials and Manufacturing		
EE 5113	VLSI System Design	
EE 5293	Topics in Microelectronics	
EE 5403	Advanced Dielectric and Optoelectronic Engineering Laboratory	
EE 5503	Introduction to Nanoelectronics	
MATE 5513	Fundamentals of Microfabrication and Application	
or EE 5413	Principles of Microfabrication	
PHY 7503	Topics in Experimental Physics (Electron Microscopy)	
PHY 7973	Special Topics in Physics (Semiconductor Device Physics)	
PHY 7973	Special Topics in Physics (Advanced Materials Characterizations)	
PHY 7973	Special Topics in Physics (Quantum Electronic Physics)	
MATE 5393	Topics in Advanced Materials Engineering	
MATE 5493	Topics in Materials Engineering and Application	
C. Prescribed Electives from Group C		**9**
Group C. Prescribed elective courses. Additional elective courses may be added with approval of the Advanced Materials Engineering Graduate Program Committee.		
CHE 5263	Advanced Analytical Chemistry	
BME 6011	Research Seminar	
BME 6723	Bioinstrumentations	
BME 6943	Biomaterials and Cell Signaling	
EE 5293	Topics in Microelectronics	
EE 6991	Research Seminar	
MATE 6951	Directed Research in Advanced Materials Engineering	
MATE 6952	Directed Research in Advanced Materials Engineering	
MATE 6953	Directed Research in Advanced Materials Engineering	
ME 5483	Finite Element Methods	
ME 5713	Mechanical Behavior of Materials	
ME 5743	Composite Materials	
ME 6013	Advanced Engineering Mathematics I	
MOT 5243	Essentials of Project Management	
MOT 5253	Starting the High-Tech Firm	
MOT 5313	Emerging Technologies	
MOT 5333	Technological Drivers of Globalization	

PHY 7503	Topics in Experimental Physics	
PHY 7503	Topics in Experimental Physics	
D. Master's Project (a minimum of 3 semester credit hours)		**3**
MATE 6943	Master's Project	
Total Credit Hours		**33**

Degree plans must be consistent with the guidelines established by the Advanced Materials Engineering Graduate Program Committee. In general, undergraduate courses of the same concentration, general education courses, and courses satisfying provisional conditions for admission cannot be counted toward the total required degree credit hours. Students enrolled through integrated B.S./M.S. program should consult the Graduate Advisor or Record for details on fulfilling the integrated degree requirement.

Comprehensive Examination

All degree candidates are required to submit a written report upon the completion of their graduate project to the student's supervising committee. Additionally, thesis degree candidates are required to pass an oral comprehensive examination. The examination is to be administered in the form of an oral presentation of the thesis or research project by the student's supervising committee. Non-thesis degree candidates have the option to be evaluated by research performance or by taking an oral comprehensive exam with the supervising committee. The committee consists of a minimum of three (for thesis option) or two (for non-thesis option) graduate faculty members; two of the members, including the committee chair, must be graduate faculty members affiliated with the MatE Master's program. Students must register for 1 semester credit hour of Comprehensive Examination (MATE 6961) for the semester in which the examination is to be taken, if they are not enrolled in other courses.

Master of Science Degree in Electrical Engineering

The Master of Science degree in Electrical Engineering is designed to offer students the opportunity to prepare for leadership roles in careers with industry, government, or educational institutions. The program has emphases in five concentrations: Computer Engineering; Systems, Control, and Robotics; Signal Processing and Learning; Communications and Intelligent Networks; Electronic Materials and Devices; and Power and Energy. A thesis option is offered for students who want the opportunity to obtain expertise in research and who may be interested in pursuing a doctoral degree in electrical engineering. A non-thesis option is available for students who want a practical industrial applications-oriented degree.

Program Admission Requirements

In addition to the University-wide graduate admission requirements, admission decisions will be based on a combination of the following:

- A bachelor's degree in electrical engineering, or in related fields for exceptional candidates.
- A minimum grade point average of 3.0 in the last 60 semester credit hours.
- Students whose native language is not English must achieve a minimum score of 79 on the Test of English as a Foreign Language (TOEFL) iBT or 6.5 on the International English Language Testing System (IELTS).

Submission of the Graduate Record Examination (GRE) is optional but recommended for consideration of competitive scholarships. A student who does not qualify for unconditional admission may be admitted on a conditional basis as determined by the Electrical Engineering Graduate Studies Committee. Applicants with an electrical engineering background who wish to continue their education but do not intend to pursue the Master of Science degree in Electrical Engineering are encouraged to seek admission as special graduate students.

Degree Requirements

The minimum number of semester credit hours required for the degree is 30 for the thesis option and 33 for the non-thesis option.

Thesis Option

The degree requires 30 semester credit hours, including 24 technical course credits and 6 thesis credits identified as EE 6983 Master's Thesis. At least 6 semester credit hours, including 3 semester credit hours of a core course, must be taken from courses in the student's concentration area. At least 3 semester credit hours of core courses must be taken outside the concentration area to satisfy the breadth requirement. No more than 3 semester credit hours of independent study should be included. One (1) semester credit hour of EE 6991 Research Seminar is required, and up to two (2) semester credit hours of EE 6991 may be included. Up to 6 semester credit hours may be taken from other graduate courses, including courses from outside electrical engineering, with approval of the Electrical Engineering Graduate Program Committee. A current list of electrical engineering graduate courses by area of concentration is available in the department office. The distribution of required courses is shown below.

Code	Title	Credit Hours
A. Core course based on student's area of concentration from the list below:		**3**
Computer Engineering Concentration		
EE 5123	Computer Architecture	
Systems, Control, and Robotics Concentration		
EE 5143	Linear Systems and Control	
Signal Processing and Learning Concentration		
EE 5163	Digital Signal Processing	
or EE 5573	Machine Learning	
Communications and Intelligent Networks Concentration		
EE 5183	Foundations of Communication Theory	
Electronic Materials and Devices Concentration		
EE 5693	Dielectric and Optoelectronic Devices	
Power and Energy Concentration		
EE 5013	Power System Analysis	
B. At least one course from student's selected concentration		**3**
C. At least one core course from outside the concentration		**3**
D. Additional graduate electrical engineering courses [1]		**9**
Must include 1 semester credit hour of EE 6991 Research Seminar		
E. Other Electives (may be courses from outside electrical engineering) [1]		**6**
F. Master's Thesis (a minimum of 6 semester credit hours are required)		**6**
EE 6983	Master's Thesis	
Total Credit Hours		**30**

[1] Chosen with approval of the Electrical Engineering Graduate Program Committee.

Non-Thesis Option

The degree requires 33 semester credit hours of technical course credits. At least 9 semester credit hours, including 3 semester credit hours of a core course, must be taken from one area to establish the student's concentration. At least 6 semester credit hours of core courses must be taken outside the concentration area to satisfy the breadth requirement. No more than 3 semester credit hours of independent study should be included. One (1) semester credit hour of EE 6991 Research Seminar is required, and up to two (2) semester credit hours of EE 6991 may be included. Up to 6 semester credit hours may be taken from other graduate courses, including courses from outside electrical engineering, with approval of the Electrical Engineering Graduate Program Committee. A current list of electrical engineering graduate courses by area of concentration is available in the department office. The distribution of required courses is given below.

Code	Title	Credit Hours
A. Core course based on student's area of concentration from the list below:		**3**
Computer Engineering Concentration		
EE 5123	Computer Architecture	
Systems, Control, and Robotics Concentration		
EE 5143	Linear Systems and Control	
Signal Processing and Learning Concentration		
EE 5163	Digital Signal Processing	
or EE 5573	Machine Learning	
Communications and Intelligent Networks Concentration		
EE 5183	Foundations of Communication Theory	
Electronic Materials and Devices Concentration		
EE 5693	Dielectric and Optoelectronic Devices	
Power and Energy Concentration		
EE 5013	Power System Analysis	
B. At least two courses from student's selected concentration		**6**
C. At least two core courses from outside the concentration		**6**
D. Additional graduate electrical engineering courses [1]		**9**
Must include 1 semester credit hour of EE 6991 Research Seminar		
E. Other Electives (may be courses from outside electrical engineering) [1]		**6**
F. Master's Project (a minimum of 3 semester credit hours are required)		**3**
EE 6943	Graduate Project	
Total Credit Hours		**33**

[1] Chosen with approval of the Electrical Engineering Graduate Program Committee.

Concentrations

The Electrical Engineering (EE) courses are divided into five concentrations as follows:

Computer Engineering

Code	Title	Credit Hours
EE 5103	Engineering Programming	3
EE 5113	VLSI System Design	3
EE 5123	Computer Architecture	3
EE 5193	FPGA and HDL	3
EE 5223	Topics in Digital Design	3
EE 5323	Topics in VLSI Design	3
EE 5423	Topics in Computer Architecture	3
EE 5453	Topics in Software Engineering	3

Systems, Control, and Robotics

Code	Title	Credit Hours
EE 5143	Linear Systems and Control	3
EE 5243	Special Topics in Control	3
EE 5343	Intelligent Control and Robotics	3
EE 5443	Discrete-Time Control Theory and Design	3
EE 5543	Non Linear System and Control	3
EE 5643	Advanced Robotics and Artificial Intelligence	3
EE 5743	Network Multi-agent Systems	3
EE 5843	Optimization and Control of Cyber-Physical Systems	3
EE 5943	Adaptive Estimation and Control	3
EE 6243	Modeling and Control of Three-Phase Pulse-width Modulated Converters	3
EE 6343	Advanced Topics in Systems and Control	3
EE 7443	Nonlinear Control Systems	3

Signal Processing and Learning

Code	Title	Credit Hours
EE 5163	Digital Signal Processing	3
EE 5253	Mathematics for Signal Processing and Machine Learning	3
EE 5263	Advanced Topics in Signal Processing and Machine Learning	3
EE 5513	Advanced Topics in Image Processing and Computer Vision	3
EE 5553	Deep Learning	3
EE 5363	Digital Image Processing	3
EE 5573	Machine Learning	3
EE 5663	Artificial Intelligence	3
EE 5763	Applied Natural Language Processing	3

Communications and Intelligent Networks

Code	Title	Credit Hours
EE 5153	Random Signals and Noise	3
EE 5183	Foundations of Communication Theory	3
EE 5283	Topics in Communications and Intelligent Networks	3
EE 5373	Wireless Communication	3
EE 5473	Fiber Optic Communication	3

EE 5583	Topics in Digital Communication	3
EE 6383	Advanced Topics in Communications	3

Electronic Materials and Devices

Code	Title	Credit Hours
EE 5293	Topics in Microelectronics	3
EE 5403	Advanced Dielectric and Optoelectronic Engineering Laboratory	3
EE 5503	Introduction to Nanoelectronics	3
EE 5593	Topics in Advanced Sensor Devices	3
EE 5693	Dielectric and Optoelectronic Devices	3
EE 6493	Advanced Topics in Electronic Materials and Devices	3

Power and Energy

Code	Title	Credit Hours
EE 5013	Power System Analysis	3
EE 5023	Power Electronics	3
EE 5033	Artificial Intelligence in Power Systems	3
EE 5053	Advanced Topics in Power and Energy Systems	3
EE 6243	Modeling and Control of Three-Phase Pulse-width Modulated Converters	3

Degree plans must be consistent with the guidelines established by the Electrical Engineering Graduate Program Committee. In general, undergraduate courses, general education courses, and courses satisfying provisional conditions for admission cannot be counted toward the total required degree credit hours.

Comprehensive Examination

Non-thesis degree candidates are required to submit a written report upon the completion of their Graduate Project to the student's advisory committee, chaired by a tenured or tenure-track graduate faculty member. In addition, an oral presentation of the project may be mandated by the advisory committee. Thesis degree candidates are required to pass an oral comprehensive examination that is administered in the form of a presentation of the thesis research to the student's advisory committee, chaired by a tenured or tenure-track graduate faculty member. Students must register for one semester credit hour of comprehensive examination for the semester in which the examination is to be taken, if they are not enrolled in other courses.

Integrated Bachelor of Science/Master of Science Program

The integrated B.S./M.S. (Bachelor of Science and Master of Science) program administered by the Department of Electrical Engineering and the Department of Computer Engineering is designed to make it possible for highly motivated and qualified B.S. students to obtain both an undergraduate degree and an advanced degree within an accelerated timeline. Through this program, motivated B.S. students can start working with their faculty advisors on research projects as early as in their senior year.

Program Admission Requirements

Applications to the B.S./M.S. program must be submitted after the completion of 75 semester credit hours of coursework.

The B.S./M.S. program applicants must have a minimum of 3.3 for both cumulative and major grade point averages. To apply for the program, students need to:

- Apply online under the category of Integrated B.S./M.S. (B.S. in Electrical Engineering or Computer Engineering, and M.S. in Electrical Engineering, Computer Engineering, or Advanced Materials Engineering); and
- Submit an official UT San Antonio transcript.

Submission of both recommendation letters and a personal statement is optional but highly recommended for consideration of scholarships.

Degree Requirements

B.S. Degree requirement: The current undergraduate degree programs in Electrical Engineering and Computer Engineering require 126 semester credit hours for completion, with fifteen of these hours (five 3-hour courses) as technical electives. Students accepted into the Integrated B.S./M.S. program will be required to complete 120 undergraduate credit hours and 6 graduate credit hours to replace two of the five undergraduate technical elective courses toward the B.S. degree. Undergraduate students wishing to voluntarily withdraw from the Integrated B.S./M.S. program must use a combination of five undergraduate technical electives and graduate organized courses to satisfy the original 126-hour regular degree program requirement in order to receive their B.S. degree. Students continuing on in the Integrated B.S./M.S. program will receive their B.S. degrees once they have earned 120 undergraduate credit hours and 6 credit hours of graduate organized courses. The 6 graduate credit hours taken as an undergraduate will be counted toward the M.S. degree requirement.

M.S. Degree requirement: A student enrolled in the Integrated B.S./M.S. program can graduate by completing requirements for a thesis or nonthesis (project) option.

(i) Thesis Option: Students must complete 30 credit hours, including 6 hours of thesis work.

(ii) Nonthesis Option: Students must complete 33 credit hours, including 3 hours of project work.

B.S./M.S. Classification

Once admitted to the Integrated B.S./M.S. program, students are allowed to take graduate courses as undergraduate students. Students admitted to the Integrated B.S./M.S. program will be reclassified from undergraduate to graduate student status when they have completed 126 semester credit hours of coursework (of any combination of graduate and undergraduate hours) toward their degrees. B.S./M.S. students can receive their B.S. degree upon completion of 126 semester credit hours, including two graduate courses, at which point the program will certify the student's eligibility to receive the B.S. degree and request the Graduate School to change the student status in the Student Information System.

Doctor of Philosophy Degree in Electrical Engineering

The Department of Electrical Engineering offers advanced coursework integrated with research leading to the Doctor of Philosophy degree

in Electrical Engineering (EE). The program has emphases in five concentrations: Computer Engineering; Systems, Control, and Robotics; Signal Processing and Learning; Communications and Intelligent Networks; Electronic Materials and Devices; and Power and Energy. The Ph.D. degree in Electrical Engineering will be awarded to candidates who have displayed an in-depth understanding of the subject matter and demonstrated the ability to make an original contribution to knowledge in their field of specialty.

The regulations for this degree comply with the general University regulations (refer to Student Policies, General Academic Regulations, and the Graduate Catalog, Doctoral Degree Regulations).

Admission Requirements

The minimum requirements for admission to the Doctor of Philosophy in Electrical Engineering degree program are as follows:

- A student is expected to hold a Bachelor's or Master's degree in Electrical Engineering or a related field before being granted admission to the program.
- Applicants with a Master's degree must have a grade point average of 3.3 or better in their Master's degree program. Applicants without a Master's degree must have a grade point average of 3.3 or better in the last 60 semester hours of undergraduate coursework in electrical engineering.
- Applicants who would like to transfer in graduate coursework from another institution or applicants admitted without an earned Master's degree in Electrical Engineering may apply a maximum of 27 semester credit hours of previously earned graduate credit toward their doctoral degree. Each student's transcript will be evaluated by the Doctoral Studies Committee, and credit will be designated on a course-by-course basis to satisfy the formal coursework requirements of the degree.
- Students whose native language is not English must achieve a minimum score of 79 on the Test of English as a Foreign Language (TOEFL) iBT or 6.5 on the International English Language Testing System (IELTS).
- Letters of recommendation, preferably three, attesting to the applicant's readiness for doctoral study, must be submitted.

A complete application includes the application form, official transcripts, letters of recommendation, a résumé, a statement of research experience, interests, and goals, and the TOEFL or IELTS score for those applicants whose native language is not English. Submission of the Graduate Record Examination (GRE) is optional but recommended for consideration of competitive scholarships. Note that admission is competitive, and satisfying these requirements does not guarantee admission.

Degree Requirements and Program of Study

The degree requires 75 semester credit hours beyond the bachelor's degree or 48 semester credit hours beyond the master's degree, passing of a qualifying examination, passing of a dissertation proposal examination, passing of a final oral defense, and acceptance of the Ph.D. dissertation. A two-semester residency research period is required.

The core courses for the five concentrations are listed below:

Code	Title	Credit Hours
EE 5123	Computer Architecture (Computer Engineering)	3
EE 5143	Linear Systems and Control (Systems, Control, and Robotics)	3
EE 5163	Digital Signal Processing (Signal Processing and Learning)	3
EE 5183	Foundations of Communication Theory (Communications and Intelligent Networks)	3
EE 5693	Dielectric and Optoelectronic Devices (Electronic Materials and Devices)	3
EE 5013	Power System Analysis (Power and Energy Concentration)	3

75 Semester Credit Hours beyond the Bachelor's Degree

The course requirements for 75 credit hours include 45 technical course credits, 15 research credits identified as EE 7951, EE 7952, and EE 7953 Doctoral Research, and 15 dissertation credits identified as EE 7991, EE 7992, and EE 7993 Doctoral Dissertation. At least two courses must be taken from the five core courses, including one related to the fundamentals of the student's doctoral research. At least one credit hour of EE 7931 Doctoral Research Seminar is required. EGR 6183 Engineering Education Methods or EGR 6283 Mentored Teaching in Engineering can be taken as a substitute for the EE 7931 Doctoral Research Seminar requirement. Up to 3 credit hours total is allowed from EE 7931 Doctoral Research Seminar and EE 6951 Independent Study combined. Up to six credit hours may be taken from other graduate courses outside electrical engineering with the approval of the Electrical Engineering Graduate Program Committee.

Code	Title	Credit Hours
A. Two core courses, including one related to the fundamentals of the student's doctoral research, from the list below		**6**
Computer Engineering Concentration		
EE 5123	Computer Architecture	
Systems, Control, and Robotics Concentration		
EE 5143	Linear Systems and Control	
Signal Processing and Learning Concentration		
EE 5163	Digital Signal Processing	
or EE 5573	Machine Learning	
Communications and Intelligent Networks Concentration		
EE 5183	Foundations of Communication Theory	
Electronic Materials and Devices Concentration		
EE 5693	Dielectric and Optoelectronic Devices	
Power and Energy Concentration		
EE 5013	Power System Analysis	
B. Graduate elective courses		**39**
At least one credit hour of EE 7931 Doctoral Research Seminar is required. EGR 6183 Engineering Education or EGR 6283 Mentored Teaching in Engineering can be taken as a substitute for the EE 7931 Doctoral Research Seminar requirement. Up to 3 credit hours total are allowed from EE 7931 Doctoral Research Seminar and EE 6951-3 Independent Study combined.		
Graduate electives chosen with approval of the Electrical Engineering Graduate Program Committee. A total of six credit hours may be chosen from outside electrical engineering.		
C. Doctoral Research		**15**
Students must complete a total of 15 credits of Doctoral Research from a combination of the courses below:		
EE 7951	Doctoral Research	

EE 7952	Doctoral Research	
EE 7953	Doctoral Research	
D. Doctoral Dissertation		**15**
Students must complete a total of 15 credits of Doctoral Dissertation from a combination of the courses below:		
EE 7991	Doctoral Dissertation	
EE 7992	Doctoral Dissertation	
EE 7993	Doctoral Dissertation	
Total Credit Hours		**75**

48 Semester Credit Hours beyond the Master's Degree

The course requirements for 48 credit hours include 18 technical course credits, 15 research credits identified as EE 7951, EE 7952, and EE 7953 Doctoral Research, and 15 dissertation credits identified as EE 7991, EE 7992, and EE 7993 Doctoral Dissertation. At least two courses must be taken from the five core courses, including one related to the fundamentals of the student's doctoral research. Up to six credit hours may be taken from other graduate courses outside electrical engineering with the approval of the Electrical Engineering Graduate Program Committee. An advanced graduate course (non-laboratory intensive) with a specified core course as prerequisite may be used, upon approval of the Graduate Advisor of Record, to satisfy the given core course requirement, if the student took the core (or equivalent) course for credit in a different degree program or at another institution. At least one credit hour of EE 7931 Doctoral Research Seminar is required. EGR 6183 Engineering Education Methods or EGR 6283 Mentored Teaching in Engineering can be taken as a substitute for the EE 7931 Doctoral Research Seminar requirement. Up to 3 credit hours total is allowed from EE 7931 Doctoral Research Seminar and EE 6951 Independent Study combined, including those earned toward the Master's degree. A Master's degree with at least 30 semester credit hours received in a closely-related field is needed for this option.

Code	Title	Credit Hours
A. Two core courses including one related to the fundamentals of the student's doctoral research, from the list below (Substitution is allowed if core courses were taken in the Master's program):		**6**
Computer Engineering Concentration		
EE 5123	Computer Architecture	
Systems, Control, and Robotics Concentration		
EE 5143	Linear Systems and Control	
Signal Processing and Learning Concentration		
EE 5163	Digital Signal Processing	
or EE 5573	Machine Learning	
Communications and Intelligent Networks Concentration		
EE 5183	Foundations of Communication Theory	
Electronic Materials and Devices Concentration		
EE 5693	Dielectric and Optoelectronic Devices	
Power and Energy Concentration		
EE 5013	Power System Analysis	
B. Graduate elective courses		**12**
At least one credit hour of EE 7931 Doctoral Research Seminar is required. EGR 6183 Engineering Education or EGR 6283 Mentored Teaching in Engineering can be taken as a substitute for the EE 7931 Doctoral Research Seminar requirement. Up to 3 credit hours total are allowed from EE 7931 Doctoral Research Seminar and EE 6951-3 Independent Study combined. Graduate electives chosen with approval of the Electrical Engineering Graduate Program Committee. If not earned at the master's level, a total of six credit hours may be chosen from outside electrical engineering.		
C. Doctoral Research		**15**
Students must complete at least 15 semester credit hours of Doctoral Research from a combination of the courses below:		
EE 7951	Doctoral Research	
EE 7952	Doctoral Research	
EE 7953	Doctoral Research	
D. Doctoral Dissertation		**15**
Students must complete at least 15 semester credit hours of Doctoral Research from a combination of the courses below:		
EE 7991	Doctoral Dissertation	
EE 7992	Doctoral Dissertation	
EE 7993	Doctoral Dissertation	
Total Credit Hours		**48**

In general, undergraduate courses, general education courses, and courses satisfying provisional conditions for admission cannot be counted toward the total required degree credit hours.

The preliminary program of study must be approved by the student's dissertation advisor and the Graduate Program Committee prior to taking the Doctoral Qualifying Examination and must be submitted subsequently upon the Dissertation Committee's approval. The courses are intended to focus and support the individual's mastery of his or her particular area of expertise.

Advancement to Candidacy

All students seeking a doctoral degree at UT San Antonio must be admitted to candidacy. One of the requirements for admission to candidacy is passing a doctoral qualifying examination. Students should consult the University's Doctoral Degree Regulations in this catalog for other requirements.

Qualifying Examination

The Ph.D. in Electrical Engineering qualifying examination ensures Knowledge Competencies through fulfillment of graduate coursework in both primary and secondary concentration areas. Successful completion of a candidacy examination is required for formal admission into the Electrical Engineering Doctoral program.

In order to establish knowledge competencies, the student must have a preliminary Program of Study on file and must submit his or her request in writing to the Graduate Advisor of Record after completion of required coursework.

The qualifying examination contains two parts: A written exam and a doctoral dissertation proposal.

Written Examination

The student must take and pass the concentration-specific written examination to demonstrate readiness to pursue a Ph.D. in the chosen concentration. Students may select a concentration with the approval of the faculty advisor. The exam is offered before the beginning of the Spring and Fall semesters. To take the written examination, students must have taken two core courses with a grade point average (GPA) of no less than 3.5. One of the core courses must be within the concentration in which the student has chosen to test. No core courses with a GPA of less than 3.0 can be counted toward the knowledge competency. An

advanced graduate course (non-laboratory intensive) with a specified core course as a prerequisite may be used, upon the approval of the Graduate Advisor of Record, to satisfy the given core courses requirement if the student took the core (or equivalent) course for credit in a different degree program or at another institution. Students must take the written examination within three semesters of enrollment in the Ph.D. EE program. Students who fail their first attempt at the written examination are allowed to make a second attempt within one semester. No more than two attempts to pass the written exam are allowed.

Dissertation Proposal Examination

Students should take the dissertation proposal exam after they have passed the written part of the Qualifying Examination (and have satisfied provisional conditions, if any). The Doctoral Dissertation Proposal should be held before a student is qualified to register for Doctoral Dissertation Courses, and it must be taken during the time period after passing the written examination and prior to the student's completion of 18 credits of doctoral research. The student must be registered and be in good academic standing to hold the dissertation proposal examination. The approved Dissertation Committee, chaired by the student's Supervising Professor, conducts the dissertation proposal exam.

The dissertation proposal exam consists of a written review of the student's dissertation research and future research plans, their defense in an oral presentation, followed by a closed oral exam administered by committee members. The committee shall examine the student's knowledge in the subject area, make recommendations for modifying the research plan, alert the student to related work, and identify potential complications. The committee may recommend additional research and/or coursework as it sees necessary. Major deviation from the proposed research requires the approval of the Dissertation Committee.

Unanimous approval of the Committee is required for the student to pass the exam. Students who fail their first attempt at the dissertation proposal exam are allowed to make a second attempt within one year. No more than two attempts to pass the dissertation proposal exam are permitted.

Final Oral Dissertation Defense

After admission to candidacy and passing the dissertation proposal exam, the next steps are conducting dissertation research, writing the dissertation, and passing the final oral defense. The final oral defense is administered and evaluated by the student's Dissertation Committee. The final oral defense consists of a public presentation of the dissertation, followed by a closed oral defense. The Dissertation Committee must unanimously approve the dissertation.

Graduate Certificate in Cloud Computing

The Graduate Certificate in Cloud Computing is a 12-semester-credit-hour program designed to equip technical professionals with the knowledge and technical skills necessary for a career in an organization that leverages cloud computing. The wide range of use of cloud computing in today's business, government, and academic environments requires a broad range of competencies and understanding of how cloud computing influences a particular area. This certificate is designed to give a common framework of understanding cloud computing, as well as allow for specialization in specific areas, such as cyber-security, cloud-infrastructure, and applications in cloud. Students may take elective courses not listed with program approval.

The certificate is administered by the Klesse College of Engineering and Integrated Design in conjunction with the College of AI, Cyber and Computing. The course requirements for each program focus may be found under the Department of Electrical Engineering (p. 1), the Department of Computer Science, (https://catalog.utsa.edu/graduate/aicybercomputing/computerscience/) and the Department of Information Systems and Cybersecurity (https://catalog.utsa.edu/graduate/aicybercomputing/informationsystemscybersecurity/).

Certificate Program Requirements

To satisfy the requirements for the Graduate Certificate in Cloud Computing, students must complete 12 semester credit hours as follows:

Code	Title	Credit Hours
A. Required Course		**3**
Select one entry course:		
EE 5523	Introduction to Cloud Computing	
Or a cross-listed course in CS and IS. The entry course is taught through team teaching in which instructors from each college contribute to the subjects outlined in the course syllabus.		
B. Track Electives		**6**
Select two courses from any of the following tracks: [1]		
Applications Track		
CS 5233	Artificial Intelligence	
CS 5263	Bioinformatics	
CS 5443	Database Management Systems	
CS 5463	Topics in Computer Science	
CS 5473	Data Mining	
CS 5493	Large-Scale Data Management	
CS 5573	Cloud Computing	
CS 6243	Machine Learning	
EE 5243	Special Topics in Control (Topic: Data Analytics with Cloud Computing)	
EE 5243	Special Topics in Control (Topic: Programming Techniques for the Cloud)	
EE 6973	Special Problems (Topic: Internet of Things)	
IS 6703	Introduction to Data Mining	
ME 5013	Topics in Mechanical Engineering (Topic: High Performance Computing)	
Security Track		
CS 6353	Network and System Security	
CS 6393	Advanced Topics in Computer Security	
IS 5513	Fundamentals of Information Assurance	
IS 6363	Digital Forensics	
Infrastructure Track		
CS 5103	Software Engineering	
CS 5123	Software Testing and Quality Assurance	
CS 6463	Advanced Topics in Computer Science	
CS 6463	Advanced Topics in Computer Science (Topic: Parallel and Distribute Systems Software)	
CS 6543	Networks	
CS 6553	Performance Evaluation	
CS 6643	Parallel Processing	
EE 5103	Engineering Programming	

EE 5453	Topics in Software Engineering (Topic: Advanced Data Structures and Algorithms)	
C. Capstone Project		**3**
Select one course from the following (topics should be in the field of Cloud Computing):		
CS 5933	Internship in Computer Science	
CS 6953	Independent Study	
CS 6983	Master's Thesis	
CS 7313	Doctoral Dissertation	
CPE 6943	Graduate Project	
CPE 6953	Independent Study	
CPE 6983	Master's Thesis	
EE 6933	Graduate Research Internship	
EE 6943	Graduate Project	
EE 6953	Independent Study	
EE 7993	Doctoral Dissertation	
IS 6933	Internship in Information Technology	
IS 6943	Internship in Cyber Security	
IS 6953	Independent Study	
IS 6983	Master's Thesis	
IS 7313	Doctoral Dissertation	
Total Credit Hours		**12**

[1] Students may take cloud course(s) not listed for credit with approval from the Certificate Program Director.

Advanced Materials Engineering (MATE) Courses

MATE 5103. Principles of Materials Engineering: Fundamentals of Structure, Chemistry, and Physical Properties. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Overviews of the fundamental underpinnings of structure-property relations of materials, which determines their behavior at the macro-, micro-, nano-, molecular- and atomic-levels, as used in passive and active components and systems for applications such as sensing, actuation, energy conversion and storage. This course has Differential Tuition.

MATE 5113. Functions, Evaluations and Synthesis Technology of Advanced Materials. (3-0) 3 Credit Hours.
Prerequisite: MATE 5103 or consent of instructor. Introduction to state-of-the-art materials processing, properties evaluation, and performance optimization of semiconductor, electroceramics, composites, nanomaterials, and thin films. This course has Differential Tuition.

MATE 5213. Sensing and Sensor Materials. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamentals of design, fabrication, and evaluation of advanced sensing materials and modern sensor technology. This course has Differential Tuition.

MATE 5223. Structure-Chemistry-Property Relations in Materials Science. (2-3) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Principles that govern assembly of crystal structures, building models of many of the technologically important crystal structures, and discussion of the impact of structure on the various fundamental mechanisms responsible for important and unique physical properties. Theory and principles are introduced along with hands-on experience of building structure models. Major topics include: Symmetry and Crystal Physics; Density, Mechanical Strength, and Anisotropy; Electronic Transport in Materials; and Thermal Properties. This course has Differential Tuition.

MATE 5233. Anisotropy and Crystalline Materials. (2-3) 3 Credit Hours.
Prerequisite: MATE 5103 or consent of instructor. Symmetry operations through coordinate transformation matrices and stereographic projections. Tensor operations applied to anisotropic crystals, polar and axial symmetries. Principle and design of sensor applications including pyroelectricity, pyromagnetism, thermal expansion, dielectric constant, magnetic susceptibility, piezoelectricity, piezomagnetism, electrostriction, magnetostriction, index of refraction, and nonlinear optical effects. Mathematica is used to model and analyze a variety of tensor properties. This course has Differential Tuition.

MATE 5243. Optic and Nonlinear Optical Materials. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Mechanisms of polarization nonlinearity, electromagnetic wave propagation in optical and nonlinear optic materials, optoelectronic materials and their device applications. This course has Differential Tuition.

MATE 5253. Magnetic Materials and Electromagnetic Engineering. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamental understanding of material responses to applied electromagnetic fields, correlated with time inversion symmetry, material chemistry, crystal structure, and microstructure for controlling and engineering electronic and magnetic properties. This course has Differential Tuition.

MATE 5393. Topics in Advanced Materials Engineering. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topics to be selected on the structure and properties, preparation and processing, characterization and performance evaluation of materials, computational modeling and simulation, with emphasis on ceramics, electronic materials, engineered composites for sensor, actuator, energy conversion and storage, or biomedical applications. May be repeated for credit as topics vary for a given concentration. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

MATE 5493. Topics in Materials Engineering and Application. (2-3) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topic 1: Advanced technology in materials/devices fabrication and property evaluation Topic 2: Micro- and nano-structure imaging and characterization Topic 3: Thermodynamic phenomenological modeling of crystalline system, computational materials simulation and finite element Multiphysics analysis Topic 4: Critical analysis of current development and literature in relevant materials research subject. Concentration I aims at sensor, actuator, energy conversion and storage applications, while Concentration II aims at biocompatible materials and biomedical applications. Instructor may specify which concentration a given topic serves in a given semester or the course serves both concentrations. May be repeated for credit as topics vary. This course has Differential Tuition.

MATE 5513. Fundamentals of Microfabrication and Application. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course describes the science of miniaturization which is essential for nanotechnology development. Microfabrication techniques for micro-electro-mechanical systems (MEMS), bioMEMS, microfluidics, and nanomaterials and their applications in biomedical research will be covered. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

MATE 5523. Biosensors: Fundamentals and Applications. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course will cover biosensing basics and in-depth view of device design and performance analysis. Topics include optical, electrochemical, acoustic, piezoelectric, and nano-biosensors. Emphasized applications in biomedical, environmental, and homeland security areas are discussed. This course has Differential Tuition.

MATE 5543. Current Analytical Tools for Biomaterials Characterizations. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course introduces the fundamentals of biomaterials characterizations and its limitations. May be repeated for credit when topics vary. This course has Differential Tuition.

MATE 6941. Master's Thesis. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. Conducted under the guidance of the Supervising Professor and the advice of the Master's Nonthesis Committee. The nonthesis project will be an independent investigation or research in the chosen concentration and is generally completed in one semester. Additionally, the nonthesis investigation will be documented, evaluated by the Master's Nonthesis Committee, and placed in the student's record indicating successful completion of the project. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. This course has Differential Tuition.

MATE 6942. Master's Thesis. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. Conducted under the guidance of the Supervising Professor and the advice of the Master's Nonthesis Committee. The nonthesis project will be an independent investigation or research in the chosen concentration and is generally completed in one semester. Additionally, the nonthesis investigation will be documented, evaluated by the Master's Nonthesis Committee, and placed in the student's record indicating successful completion of the project. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. This course has Differential Tuition.

MATE 6943. Master's Thesis. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. Conducted under the guidance of the Supervising Professor and the advice of the Master's Nonthesis Committee. The nonthesis project will be an independent investigation or research in the chosen concentration and is generally completed in one semester. Additionally, the nonthesis investigation will be documented, evaluated by the Master's Nonthesis Committee, and placed in the student's record indicating successful completion of the project. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. This course has Differential Tuition.

MATE 6951. Directed Research in Advanced Materials Engineering. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing and permission in writing of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. This course has Differential Tuition.

MATE 6952. Directed Research in Advanced Materials Engineering. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing and permission in writing of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. This course has Differential Tuition.

MATE 6953. Directed Research in Advanced Materials Engineering. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing and permission in writing of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. This course has Differential Tuition.

MATE 6961. Comprehensive Examination. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record. Independent study course for the purpose of taking the Comprehensive Examination. May be repeated for credit as many times as approved by the Graduate Studies Committee. Enrollment is required each term in which the Comprehensive Examination is taken if no other courses are being taken that term. The grade report for the course is either "CR" (satisfactory performance on the Comprehensive Examination) or "NC" (unsatisfactory performance on the Comprehensive Examination). This course has Differential Tuition.

MATE 6981. Master's Thesis Research. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record and Thesis Advisor. Thesis research and preparation conducted under the guidance of the Supervising Professor and the advice of the Master's Thesis Committee. The thesis is an original contribution to scholarship, based on intense independent investigation or graduate research in the chosen concentration. Thesis option students are required to successfully present and defend their thesis, which serves as the oral comprehensive examination for the thesis option. Final approval of the thesis by the Graduate School will serve as an indication of the successful completion of the research. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

MATE 6982. Master's Thesis Research. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Thesis Advisor. Thesis research and preparation conducted under the guidance of the Supervising Professor and the advice of the Master's Thesis Committee. The thesis is an original contribution to scholarship, based on intense independent investigation or graduate research in the chosen concentration. Thesis option students are required to successfully present and defend their thesis, which serves as the oral comprehensive examination for the thesis option. Final approval of the thesis by the Graduate School will serve as an indication of the successful completion of the research. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

MATE 6983. Master's Thesis Research. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Thesis Advisor. Thesis research and preparation conducted under the guidance of the Supervising Professor and the advice of the Master's Thesis Committee. The thesis is an original contribution to scholarship, based on intense independent investigation or graduate research in the chosen concentration. Thesis option students are required to successfully present and defend their thesis, which serves as the oral comprehensive examination for the thesis option. Final approval of the thesis by the Graduate School will serve as an indication of the successful completion of the research. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

Electrical Engineering (EE) Courses

EE 5013. Power System Analysis. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Electric energy and environment, principles of power generation, transmission and distribution, power flow analysis, faults and transient stability analysis, power systems control, and renewable energy systems. This course has Differential Tuition.

EE 5023. Power Electronics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Switching power converter operation and design; modeling of power converters; power components including power semiconductor devices, inductors, and transformers; control of power converters; and select power converter topology for applications such as renewable energy, electric transportation, and telecommunications. Learning objectives: Analyze the basic operation of switching power converters; simulate the detailed, average, and small-signal operation of power converters; use steady-state, average, and small-signal models of pulse width modulation switch in power converter analysis and design; design of converter power stage for steady-state specifications; and design feedback controller of converters for dynamic specifications. This course has Differential Tuition.

EE 5033. Artificial Intelligence in Power Systems. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Basic principles of AI tools used in electric power systems such as Artificial Neural Networks, Fuzzy Logic, Evolutionary Computing, Genetic Algorithms, Multiagent Systems, and Stochastic Optimization. Application of AI tools in electricity management, fault detection, unit commitment, operation optimization, decision-making, grid control and forecasting, and electricity market operation. It is expected that after successful completion of the class, the student will have the basic knowledge of how to develop systems applied to electric power systems and electricity markets. This course has Differential Tuition.

EE 5053. Advanced Topics in Power and Energy Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 2423, or PHY 1603 and EGR 2323, and graduate standing or consent of instructor. Topics may include the following: 1) Electric Distribution System Modeling and Analysis and Introduction to Distribution Systems. Nature of loads. Series impedance and shunt admittance of overhead and underground lines. Voltage regulation. Three-phase transformer models. Load models. Power flow analysis. Center-tapped transformers and secondaries. Short-circuit studies 2) Nuclear Engineering and Applications; This is an introductory course for graduate students in electrical engineering desiring a nuclear energy sequence and an elective course for students in science and other engineering disciplines. The course aspires to cover the basic knowledge and principles in nuclear energy and engineering and is structured in six parts. (i) Nuclear physics and radiation interactions, (ii) Basics of radiation detection, (iii) Nuclear reactors and nuclear power, (iv) Electric Utility and Nuclear Power Economics, (v) Nuclear Energy, Renewables and Environment, and vi) nuclear instruments and sensors with artificial intelligence applied to nuclear safety, industry and medicine. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5103. Engineering Programming. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Object oriented programming for engineering design problems using C++; software development for mathematical modeling and simulation of hardware systems; extraction and reporting (e.g., text processing) using scripting languages such as Perl; and individual class projects. This course has Differential Tuition.

EE 5113. VLSI System Design. (3-1) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. VLSI Circuit Design, CMOS technology and device modeling, structured digital circuits, VLSI systems; computer-aided design tools, placement, routing, extraction, design rule checking, graphic editors, simulation, verification, minimization, silicon compilation, test pattern generation, theory for design automation, and chip design. (Formerly EE 5323 Topic 1: VLSI I. Credit cannot be earned for both EE 5113 and EE 5323 VLSI I.) This course has Differential Tuition.

EE 5123. Computer Architecture. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Description of digital computer systems, arithmetic algorithms, central processor design, memory hierarchies and virtual memory, control unit and microprogramming, input and output, coprocessors, and multiprocessing. This course has Differential Tuition.

EE 5143. Linear Systems and Control. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Advanced methods of analysis and synthesis of linear systems, continuous and discrete-time systems, analytical approach to linear control theory. This course has Differential Tuition.

EE 5153. Random Signals and Noise. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study of probability theory, random processes, mean and autocorrelation, stationarity and ergodicity, Gaussian and Markov processes, power spectral density, noise, and linear systems. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 5163. Digital Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study of discrete-time signals and systems, including Z-transforms, fast Fourier transforms, and digital filter theory. Filter design and effects of finite register length, and applications to one-dimensional signals. This course has Differential Tuition.

EE 5183. Foundations of Communication Theory. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor, completion of EE 5153 recommended. Basis functions, orthogonalization of signals, vector representation of signals, optimal detection in noise, matched filters, pulse shaping, intersymbol interference, maximum likelihood detection, channel cutoff rates, error probabilities, bandwidth, and power-limited signaling. This course has Differential Tuition.

EE 5193. FPGA and HDL. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamental digital systems principles. HDL modeling concepts and styles: structural, RTL, and behavioral; modeling for synthesis and verification; modeling combinatorial and sequential logic circuits; modeling finite state machines; testbench developments; performance estimation and improvement. (Formerly EE 5223 Topic 2: FPGA and HDL. Credit cannot be earned for both EE 5193 and EE 5223 FPGA and HDL.) This course has Differential Tuition.

EE 5223. Topics in Digital Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor. Topics may include the following: Topic 1: Graph Theory and Networking. Introduction to graphs and digraphs, applications of graphs, Eulerian and Hamiltonian graphs, connectivity, trees, planar graphs, decomposition problems, graph models for electrical and communications networks and computer architectures, communications network application examples, analysis and design. Topic 2: Microcomputer-Based Systems. 8- and 16-bit microprocessors, bus timing analysis, interfacing principles, LSI and VLSI chip interfacing, use of software development tools such as assemblers, compilers, and simulators, and hardware development tools including logic analyzer. Topic 3: PCI System Design. Understanding PCI specifications including protocol, electrical, mechanical, and timing. Study the protocol for high-speed, high-bandwidth data throughput. Designing a PCI-based system design and implementing in FPGA. May be repeated for credit as topics vary. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 5243. Special Topics in Control. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Topics may include the following: Topic 1: Optimal Control. Optimal and suboptimal techniques for controller design using the principle of optimality, min-max principles, and induced norm minimization. Topic 2: Computational Intelligence. A study of neuron models, basic neural nets and parallel distributed processing, and sound mathematical intuition and applications about neural network algorithms and architectures. Includes theory of fuzzy sets, foundations of fuzzy logic, and genetic algorithms. The course emphasizes engineering applications: control, pattern recognition, damage assessment, and decisions. Topic 3: System of Systems Science and Engineering. Introduction to Systems Engineering, Large-Scale Complex Systems, System of Systems (SoS). Architecture and Modeling of System of Systems Engineering, Distributed and Cooperative Control of SoS, discrete-event simulation systems (DEVS) principles and applications, Autonomous Control Systems via Computational Intelligence Tools, principle component analysis and data mining techniques for SoS, V-Lab a Virtual Laboratory and Matlab software for intelligent SoS, case studies: Sensor Networks, System of Robots, Future Combat Systems, Wireless Networks, and System of Energy. Topic 4: Advanced Topics of Embedded Control Systems. Study control techniques for embedded systems. Emphasis on hybrid system configuration, data acquisition, and sensing and fundamentals for motion control systems. Control schemes include NI DAQ-based control and FPGA-based control. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5253. Mathematics for Signal Processing and Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course covers fundamental and advanced linear algebra concepts such as vectors, matrices, factorizations, norms, and least squares. It delves into probability theory and random processes, including joint/conditional probabilities, Bayes' theorem, multivariate distributions, and moments. In the domain of multivariate calculus, gradients and Hessians are explored. Basic optimization topics include convex optimization, KKT conditions, and elements of stochastic optimization. Additional subjects include complex analysis and signal/systems theory, encompassing sampling theory, convolution, filtering, LTI systems, interpolation, and Fourier transform. This course has Differential Tuition.

EE 5263. Advanced Topics in Signal Processing and Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: EE 5153 or EE 5163, or consent of instructor. Topics may include the following. Topic 1: Nonlinear Filters. Includes order statistic filters, morphological filters, stack/Boolean filters, and other related topics. Topic 2: Detection and Estimation Theory. Includes minimum-variance unbiased estimation, Cramer-Rao low bound, maximum-likelihood estimation, Bayesian estimation, Neyman-Pearson detector, Bayesian detector, matched filter, and Generalized Likelihood Ratio Test. Topic 3: Orthogonal and Wavelet Transforms with Applications. Includes a broad spectrum of orthogonal transforms, including Cosine, Sine, Hartley, Haar, Slant, Short-time Fourier, Gabor, and Walsh, along with wavelet and sub-band decompositions. Covers the construction, properties, and multiresolution analysis of wavelets and wavelet packets and applications in image and video compression standards, signal and image denoising, steganography, and watermarking. Topic 4: Signal Processing for Wireless Systems. Converse use of transforms for the analysis and design of wireless systems, filter design, and/or adaptive antenna-array processing. Topic 5: Information Theory. Covers concepts like entropy, information content, channel capacity, and the fundamental limits of signal processing and communication systems. Topic 6: Game Theory. Covers mathematical modeling of conflict and cooperation between rational decision-makers, classic games analysis, Nash equilibrium, and the impact of asymmetric information. Includes application examples to real-world scenarios such as wireless communications and AI agents. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5283. Topics in Communications and Intelligent Networks. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topics may include the following: Topic 1: Spread Spectrum Communications and GPS. Spread Spectrum (SS) Signals and Systems, Theory of Pseudorandom Sequences, Synchronization (Acquisition, Tracking), CDMA and Global Positioning Systems (GPS, A-GPS, Galileo), Simulations of SS Systems. Topic 2: Simulation of Communication Systems. Simulation and implementation of representative communication systems, Automatic Gain Control (AGC), modulation/demodulation, pulse shaping and matched filters, carrier and time recovery, equalizers, fast correlators. Practical filter design for communication systems. Topic 3: Wireless Communications and Networks. Communication systems, modulation techniques, Spread Spectrum, multiple access techniques, coding, error detection and correction, cellular systems, satellite systems, mobile communications, antennas, networks, TCP/IP suite, network protocols, Mobile IP, Wireless LANs, IEEE 802 standards. Topic 4: 5G Wireless Communications. Concepts, theory, and object oriented modeling of 5G cellular systems in Matlab from the perspective of 3GPP 5G Core Networks (LTE).Coverage includes multi-carrier modulation, OFDMA, fading, multiple antenna systems, diversity, Massive MIMO, millimeter wave communications, adaptive modulation and coding, H-ARQ and system ergodic and outage capacity. 5G Core Networks, Service Based Architectures (SBA), Network Function Virtualization (NFV), Virtualized RAN, Physical Layer Systems, Combined Artificial Intelligence and 5G, and Introduction to 6G. Topic 5: Communication Networks. Introduction and layered network architecture. Point-to-point communication and datalink control (error detection, automatic repeat request protocols, link initialization and disconnect protocols). Delay models in database networks(elements of queueing theory). Multiaccess communication (Aloha, collision resolution protocols, carrier sense multiple access, reservation-based protocols). Routing (packet switching, minimum weight spanning trees, shortest path routing). The Internet Protocol (IP). Transport layer protocols. Flow control. Topic 6: Optimization in Engineering and Data Science. Convex sets and functions. Convex optimization problems: Linear, quadratic, geometric, and semidefinite programming. Optimality conditions. Lagrangian duality. Optimization algorithms: Gradient methods, Newton's method, Lagrange multiplier methods, interior point methods, subgradient methods. Optimization Under Uncertainty and Distributed Optimization. Applications in different areas of Engineering (electric energy systems, control systems, state estimation, optimal network flow for infrastructure systems such as communications, transportation, water), and Data Science (least squares problems, regression models, sparsity/model-selection regularizations, estimation, classification and support vector machines). Topic 7: Computer Network Security. Encryption techniques, symmetric ciphers, public key cryptography, Hash Functions, authentication, email security, IP security, Web security, wireless network security, firewalls. Topic 8: Error Correcting Code. Analysis of error control codes in communication systems, disk drives, satellite communications, and cellular systems, Galois Field Algebra, systematic and non-systematic codes, recursive codes, BCH Codes, Cyclic Codes, Syndrome Decoding, Convolutional Coding and Decoding, Soft Output Viterbi Algorithm (SOVA), Iterative Codes, 5G Error correction Codes, Low Density Parity Check Codes (LDPC), Erasure Codes in data base systems. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5293. Topics in Microelectronics. (3-0) 3 Credit Hours.
Prerequisite: EE 4313. Topics may include the following: Topic 1: Analog Integrated Circuit Design. Introduction to MOS devices and analog circuit modeling. Analog circuits: active resistors, current sources, current mirrors, current amplifiers, inverting amplifier, differential amplifier, cascade amplifier, MOS switches, and the output amplifier. Complex circuits: comparators, operational amplifiers, and other commonly used building blocks for mixed signal systems. Use of CAD tools to layout and simulate analog circuits. Topic 2: Mixed Signal Circuits and Systems. Introduction to the circuits of systems in which analog and mixed signal integrated circuit design are employed. The topics are A/D and D/A converters, including Nyquist-rate and oversampling A/D converters, switched capacitor filters, multipliers, oscillators, the PLL, and circuit design issues, testing, digital calibration and correction. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5323. Topics in VLSI Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5113 or consent of instructor. Topic 1: Advanced VLSI Design. Microelectronic systems architecture; VLSI circuit testing methods; integration of heterogeneous computer-aided design tools; wafer scale integration; advanced high-speed circuit design and integration. Engineering design of large-scale integrated circuits, systems, and applications; study of advanced design techniques, architectures, and CAD methodologies. Topic 2: Low Power VLSI Design. Hierarchy of limits of power, source of power consumption, voltage scaling approaches; circuit, logic, architecture and system level power optimization; power estimation; advanced techniques for power optimization; software design for low power. Topic 3: VLSI Testing. Digital system design verification; logic and fault simulation; testbench guidelines; functional coverage; VLSI manufacturing test; fault modeling; testability measures; Design for Testability (DFT); and Automatic Test Pattern Generation (ATPG). Topic 4: VLSI Performance Analysis and Optimization. Delay models, delay calculation, signal integrity effects, timing analysis, performance variability, performance optimization, and delay test. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5343. Intelligent Control and Robotics. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Study of artificial neural networks control, knowledge-based control, and fuzzy-logic control. Analytical techniques and fundamental principles of robotics; dynamics of robot arms, motion control, robot sensing, and robot intelligence. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 5353. Topics in Multimedia Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: EE 5153 or EE 5163, or consent of instructor. Topics may include the following: Topic 1: Digital Image Processing. Study of binary image processing; histogram and point operations; algebraic and geometric image operations; 2-D digital Fourier transforms; convolution; linear and nonlinear filtering; morphological filters; image enhancement; linear image restoration (deconvolution); digital image coding and compression; and digital image analysis. (Formerly EE 5363. Credit cannot be earned for both EE 5353 Topic 1: Digital Image Processing and EE 5363.) Topic 2: Computer Vision and Application. Image perception, edge detection in the visual system, future vectors, image enhancement, shape from shading, image segmentation by textural perception in humans, chain codes, B-splines, classification (SVM and others). Topic 3: Biomedical Image Processing. This course will examine the fundamental and mathematical aspects of imaging; new algorithms and mathematical tools for the advanced processing of medical and biological images, which include fundamental methods of image reconstruction from their projections, multi-modal imaging, image analysis and visualization, image enhancement, image segmentation and gene-expression calculation, image parameter estimation and measurements, target location, texture synthesis and analysis, morphological image processing, processing of microarray images, processing of FISH stacked images, automated analysis of gene copy numbers by fluorescence in situ hybridization, image acquisition and processing in major imaging techniques, including magnetic resonance, 2-D and 3-D computed tomography, positron emission tomography, and others. Topic 4: Development of Multimedia Applications for Wireless Devices. Programming on wireless systems. Multimedia (image, audio and video) formats. Multimedia processing. Development of sample applications. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5363. Digital Image Processing. (3-0) 3 Credit Hours.
Prerequisites: EE 5153 and EE 5163; or instructor's approval. This course delves into the core techniques of image processing. Topics include binary image processing, histogram and point operations, geometric operations on images, 2-D digital Fourier transforms, Hadamard and cosine transforms, and convolution methods. The curriculum includes both linear and nonlinear filtering, morphological filters, image enhancement, color image processing, and linear image restoration, including deconvolution techniques. It also covers the critical areas of image reconstruction by projections, digital image coding, compression, and detailed image analysis. This course has Differential Tuition.

EE 5373. Wireless Communication. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course offers an in-depth study of wireless communication systems, propagation modeling for wireless systems, the physical layer and modulation schemes used for wireless channels, diversity techniques, and multiple access schemes used in wireless systems. This course has Differential Tuition.

EE 5403. Advanced Dielectric and Optoelectronic Engineering. (2-4) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topic 1: Principles of Dielectric Devices. Evaluation of capacitance devices, impedance frequency and temperature spectrum analysis, characterization of tunable dielectric microwave materials, characterization of piezoelectric devices. Topic 2: Principles of Optical Components and Systems. Lasers, photo-detectors, phase locked interferometer, electro-optical and nonlinear optic devices, optical image processing, Fourier optics, holographic recording, and photorefractive storage. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5413. Principles of Microfabrication. (2-3) 3 Credit Hours.
Prerequisite: Graduate standing or completion of EE 3323. Fundamentals of microfabrication techniques, including photolithography, thin film deposition (physical vapor deposition and chemical vapor deposition), etching, thermal oxidation, diffusion, ion implantation, chemical and mechanical polishing, and epitaxy. Nanofabrication techniques that enable sub-micron feature sizes will also be discussed (electron beam or x-ray lithography, focused ion beam, and other bottom-up approaches). Students will visit nearby research institutes and foundry companies as part of this course. (Credit cannot be earned for both EE 4533 and EE 5413. Same as ME 5803. Credit cannot be earned for both EE 5413 and ME 5803.) Generally offered: Fall. This course has Differential Tuition.

EE 5423. Topics in Computer Architecture. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor. Topic 1: Parallel and Distributed Computing. Multiprocessor and multicomputer systems, shared-memory and distributed memory systems, exploitation of parallelism, data partitioning and task scheduling, multiprocessor system interconnects, message passing and data routing, parallel programming. Topic 2: RISC Processor Design, RISC Concept. RISC versus CISC, RISC advantages and disadvantages, various processor survey and applications, study of software development tools: assemblers, compilers, simulators, RISC implementations. Topic 3: Superscalar Microprocessor Architecture. Definition of superscalar, superpipelined, and VLIW processors; available parallelism in programs; branch prediction techniques; memory systems for superscalar processors; trace caches; memory disambiguation and load/store recording; performance evaluation techniques; multimedia extensions in superscalar processors. Topic 4: Fault Tolerance and Reliable System Design. Reliability and availability techniques, maintainability and testing techniques, evaluation criteria, fault-tolerant computing, fault-tolerant multiprocessors, design methodology for high reliability systems. Topic 5: Computer Arithmetic. Fundamental principles of algorithms for performing arithmetic operations in digital computers. Number systems, fast implementations of arithmetic operations and elementary functions, design of arithmetic units using CAD tools. Topic 6: Advanced Computer Architecture. Superscalar and vector processors, advanced pipelining techniques, instruction-level parallelism and dynamic scheduling techniques, advanced memory hierarchy design. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5443. Discrete-Time Control Theory and Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Control theory relevant to deterministic and stochastic analysis and design of computer-controlled systems using both state-space and input-output models. This course has Differential Tuition.

EE 5453. Topics in Software Engineering. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor; concurrent enrollment in QST 6003 is recommended. Topic 1: Large Domain-Specific Software Architectures. Software engineering approaches; scenario-based design processes to analyze large problem domains; domain modeling and representations; creation of component-based architecture providing an object-oriented representation of system requirements; and development of large software class projects. Topic 2: Embedded Software Systems Design. This topic covers dataflow models, uniprocessor and multiprocessor scheduling, hardware/software codesign, hierarchical finite state machines, synchronous languages, reactive systems, and heterogeneous systems. Topic 3: Embedded Software Testing and Quality Assurance. Systematic testing of embedded software systems; unit (module), integration, and system-level testing; software verification; hardware/software cotesting; code inspections; use of metrics; quality assurance; measurement and prediction of software reliability; software maintenance; software reuse and reverse engineering. Topic 4: Advanced Engineering Programming. Programming in the cloud, advanced engineering design problems and techniques using C++ and Java, advanced data structures and complexity analysis of algorithms, dynamic programming using Perl and Python, and large-scale and real-world group and individual projects. Topic 5: Quantum sensing is the most advanced area of quantum information science and engineering, with technological applications currently available on the market. This course will examine spin qubits such as diamond vacancy centers, trapped ions, flux qubits in superconducting circuits, nanoparticles, and photonic quantum systems. Foundational properties and techniques of quantum mechanics, such as perturbation theory, quantum entanglement, quantum interference, and quantum state squeezing, will be covered in depth and used to create sensors with sensitivity and accuracies greater than traditional classical approaches. Quantum sensing of magnetic, electric, gravitational, and broadband electromagnetic fields will be studied, with applications from position, navigation, and timing in GPS-denied environments to the measurement of new space-time scales in the brain via quantum sensor arrays in magnetoencephalography. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5473. Fiber Optic Communication. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. In-depth study of fiber optic principles, performance of optical receivers, devices, digital and analog fiber optic transmission systems, wavelength division multiplexing systems, optical amplifiers, and fiber optic measurements. This course has Differential Tuition.

EE 5503. Introduction to Nanoelectronics. (2-3) 3 Credit Hours.
Prerequisite: Graduate standing or completion of EE 3323. Fundamentals of semiconductor device physics. State-of-the-art CMOS and beyond-CMOS device technologies. Quantum transport theories of electron, phonon, and spin in nanoscale solids. Nanofabrication techniques. Low-dimensional nanomaterials for future electronics. Practical application of nanotechnology in mechanical, optical, and biological heterogeneous systems. Students will study a quantum phenomenon using a device simulation software. (Credit cannot be earned for both EE 4523 and EE 5503. Same as ME 5883. Credit cannot be earned for both EE 5503 and ME 5883.) Generally offered: Spring. This course has Differential Tuition.

EE 5513. Advanced Topics in Image Processing and Computer Vision. (3-0) 3 Credit Hours.
Prerequisite: EE 5153 and EE 5163, or consent of instructor. Topics may include the following: Topic 1: Biomedical Image Processing. The course covers medical and biological image processing, projection-slice theorem, and Radon transform, including image reconstruction by parallel projections, enhancement, and multimodal techniques, along with MRI, CT, and PET imaging applications. Topic 2: Quantum Image Processing. Covering quantum gates and algorithms and their applications in color and grayscale image processing. Students will learn about quantum image representation and processing techniques through a combination of lectures and projects. Topic 3: Computer Vision and Applications. Students explore the core principles of computer vision, from image perception and edge detection to classification with SVMs, applying these concepts to practical domains using tools like chain codes and B-splines. This course has Differential Tuition.

EE 5523. Introduction to Cloud Computing. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study in concepts related to cloud computing including key components of cloud computing, networking fundamentals, Python programming, resource allocation using cloud APIs, introduction to parallel programming with Python using MPI, data analytics fundamentals such as relational database theory, SQL/noSQL, and Map/Reduce. This course has Differential Tuition.

EE 5543. Nonlinear System and Control. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Nonlinear systems modeling, existence and uniqueness of solutions, phase plane analysis, Lyapunov stability analysis, Lyapunov based nonlinear control techniques. This course has Differential Tuition. Course Fee: L001 $15.

EE 5553. Deep Learning. (3-0) 3 Credit Hours.
Prerequisite: EE 5153. This course will introduce the basic concept of deep learning and cover most important deep learning models including deep neural networks, convolutional networks, and recurrent neural networks. The course will also cover applications of deep learning in computer vision, natural language processing, computational biology, and other areas. This course has Differential Tuition.

EE 5563. Statistical Inference. (3-0) 3 Credit Hours.
Prerequisite: EE 5153. Fundamentals of hypothesis testing and parameter estimation including likelihood ratio test, unbiased estimation, and minimax estimation. Parametric and nonparametric inference with elements of large sample theory. Graphical models with exact and approximate inference methods including Markov chain Monte Carlo methods and variational inference. Elements of sequential inference including change point detection, hidden-Markov models, and time-series analysis. This course has Differential Tuition.

EE 5573. Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: EE 5153; or instructor's approval. This course introduces the fundamental concepts of machine learning, including supervised, unsupervised, semi-supervised, and reinforcement learning paradigms. It presents both discriminative and generative learning, along with parametric and nonparametric models. The curriculum includes an examination of training, testing, and validation techniques such as cross-validation and statistical methods, including maximum-likelihood and maximum-a-posteriori-probability estimation. Students will have the opportunity to explore various regression models, including linear and non-linear approaches, regularization methods such as ridge and lasso, kernel techniques, logistic regression, classification algorithms, support vector machines, and the perceptron model. The course also focuses on unsupervised learning with a focus on dimensionality reduction, feature selection, and clustering. Potential advanced topics include multi-layer perceptrons, neural networks, stochastic parameter optimization, and backpropagation. The course also includes programming exercises and practical experimentation. This course has Differential Tuition.

EE 5583. Topics in Digital Communication. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topics may include the following: Topic 1: Digital Information Theory. Entropy and mutual information; Huffman coding; source and channel coding theorems; channel capacity; block coding error bounds; random coding bounds; cutoff rate; multiuser information theory; random access channels and protocols; multiaccess coding methods. Topic 2: Digital Modulation Schemes. In-depth study of digital modulation; information sources and source coding, quantization, representation of digitally modulated signals; synchronization and timing issues in digital communications. Topic 3: Computer Communication Networks. Fundamentals of communication networks, data communication and transmission systems, peer-to-peer protocols, local/wide area networks, multiple access methods, and service integration. Topic 4: Coding and Error Correction. Algebraic Coding Theory; groups and fields, linear codes, Hamming distance, cyclic codes, minimum distance bounds, BACH codes and algebraic decoding, Reed-Solomon codes, Reed-Mueller codes and maximum likelihood decoding, suboptimal decoding, and applications of coding. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5593. Topics in Advanced Sensor Devices. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamentals of materials parameters to design nano-micro level pyroelectric, piezoelectric, ferroelectric and various electronic sensors and actuators. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5643. Advanced Robotics and Artificial Intelligence. (3-0) 3 Credit Hours.
Introduction and review of manipulator robots, mobile robotics navigation, localization, sensing and control. Drones modeling and control, AI and machine Learning, clustering, PCA, regression, evolutionary computing, fuzzy systems, deep learning, deep neural networks, and projects. This course has Differential Tuition.

EE 5663. Artificial Intelligence. (3-0) 3 Credit Hours.
An introduction to the theories and algorithms used to create artificial intelligence (AI) systems. Topics include search algorithms, logic, probabilistic reasoning, planning, and applications from areas such as computer vision, robotics, and natural language processing. Programming assignments will be provided. This course has Differential Tuition.

EE 5693. Dielectric and Optoelectronic Devices. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Introduction to functional dielectric and optoelectronic materials and devices. Dielectric polarization, relaxation, loss and breakdown properties. Mechanisms of piezoelectric, pyroelectric, and electro-optic properties of solid state materials. This course has Differential Tuition.

EE 5743. Network Multi-agent Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. This course will cover basic network sciences, graph theories, multi-agent system modeling and control, swarms, and social networks. The course will prepare students with fundamental tools to analyze and design network systems with applications in robotics, power systems, social networks, biological networks, and distributed computing and optimization. This course has Differential Tuition.

EE 5763. Applied Natural Language Processing. (3-0) 3 Credit Hours.
Prerequisite: EE 5253; or instructor's approval. This is an interdisciplinary course that introduces students to the design and implementation of Natural Language Processing (NLP) through a project-based approach. Students will learn to design and use NLP methods (such as transformer models and large language models) and creatively apply them to real-world projects, for example, RNA sequence analysis, language translation, text summarization, and security applications. During this course, students have access to state-of-the-art graphics processing units (GPUs) for extensive experimentation. In addition to lectures, the course will invite speakers who are experts in NLP, Machine Learning, and Deep Learning. This course has Differential Tuition.

EE 5843. Optimization and Control of Cyber-Physical Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Modeling of cyber-physical systems; applications in complex urban infrastructure; mathematical optimization; semidefinite programming; dynamic state estimation; robust feedback control; networked control systems; modeling time-delays and cyber-attacks within CPSs; model predictive control. This course has Differential Tuition.

EE 5943. Adaptive Estimation and Control. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Current methods in adaptive systems and control including stability analysis, convergence, robustness, system identification, recursive parameter estimation, and design of parameterized controllers. This course has Differential Tuition.

EE 5993. AI Practicum. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This AI practicum course includes weekly AI seminar which provides insights on the current state of the AI and ML technologies and covers a wide variety of AI topics, such as computer vision, natural language processing (NLP), theoretical ML, AI fairness & ethics, cognitive science, AI hardware, etc. The seminars will include speakers from industry and academia, who discuss the state of the practice with real use cases and methodologies to make AI projects a tangible success. The practicum also offers an experiential training opportunity to apply AI to problems in the real world. Standard AI programming tool suites and design flow concepts will be learned through the mini-project. Students will also be introduced to how AI is impacting society, the ethics of AI solutions, concerns surrounding AI, and deploying AI in complex scenarios. Python programming experience is needed. This course has Differential Tuition.

EE 6243. Modeling and Control of Three-Phase Pulse-width Modulated Co nverters. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Develop understanding of power conversion principles in three-phase Pulse-width Modulated (PWM) converters and learn to design the control for the converters used in most applications through: use of switching state vectors and different modulation schemes, development of averaged models of rectifiers and inverters in stationary and rotating coordinates, small-signal modeling in rotating coordinates, and closed loop control design. This course has Differential Tuition.

EE 6343. Advanced Topics in Systems and Control. (3-0) 3 Credit Hours.
Prerequisite: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the systems and control area. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6363. Advanced Topics in Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the signal processing area. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6383. Advanced Topics in Communications. (3-0) 3 Credit Hours.
Prerequisite: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the communications area. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6493. Advanced Topics in Electronic Materials and Devices. (2-3) 3 Credit Hours.
Prerequisite: EE 5693 and EE 5503 or EE 5593 or consent of instructor. Topics to be selected from advanced sensors, actuators, engineered materials, device physics, microwave applications of MEMS structures, optoelectronics and photonics, microelectronic devices and nanotechnology. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6931. Graduate Research Internship. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either "CR" (satisfactory performance on Graduate Research Internship) or "NC" (unsatisfactory performance on Graduate Research Internship). This course has Differential Tuition.

EE 6932. Graduate Research Internship. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either "CR" (satisfactory performance on Graduate Research Internship) or "NC" (unsatisfactory performance on Graduate Research Internship). This course has Differential Tuition.

EE 6933. Graduate Research Internship. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either "CR" (satisfactory performance on Graduate Research Internship) or "NC" (unsatisfactory performance on Graduate Research Internship). This course has Differential Tuition.

EE 6941. Graduate Project. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) This course has Differential Tuition.

EE 6942. Graduate Project. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) This course has Differential Tuition.

EE 6943. Graduate Project. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) This course has Differential Tuition. Course Fee: DL01 $75.

EE 6951. Independent Study. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition.

EE 6952. Independent Study. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition.

EE 6953. Independent Study. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition.

EE 6961. Comprehensive Examination. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record. Independent study course for the purpose of taking the Comprehensive Examination. May be repeated for credit as many times as approved by the Graduate Studies Committee. Enrollment is required each term in which the Comprehensive Examination is taken if no other courses are being taken that term. The grade report for the course is either "CR" (satisfactory performance on the Comprehensive Examination) or "NC" (unsatisfactory performance on the Comprehensive Examination). This course has Differential Tuition.

EE 6973. Special Problems. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Problems courses may be repeated for credit when topics vary, but not more than 6 hours, regardless of discipline, may be applied to the degree. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 6981. Master's Thesis. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

EE 6982. Master's Thesis. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

EE 6983. Master's Thesis. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

EE 6991. Research Seminar. (1-0) 1 Credit Hour.
Organized research lectures and seminar presentations. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). This course may include a written component. May be repeated for credit, but not more than 1 hour will apply to the Master's degree, regardless of discipline. This course has Differential Tuition.

EE 7443. Nonlinear Control Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Principles of nonlinear systems analysis: Lyapunov stability, input-output stability, and homogeneous system theory. Control of nonlinear systems: integrator backstepping, feedback domination, Lyapunov-based design, small control technique, output feedback design, and applications to physical systems. This course has Differential Tuition.

EE 7931. Doctoral Research Seminar. (1-0) 1 Credit Hour.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. This course has Differential Tuition.

EE 7932. Doctoral Research Seminar. (2-0) 2 Credit Hours.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. This course has Differential Tuition.

EE 7933. Doctoral Research Seminar. (3-0) 3 Credit Hours.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. This course has Differential Tuition.

EE 7951. Doctoral Research. (0-0) 1 Credit Hour.
Prerequisite: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7952. Doctoral Research. (0-0) 2 Credit Hours.
Prerequisite: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7953. Doctoral Research. (0-0) 3 Credit Hours.
Prerequisite: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7991. Doctoral Dissertation. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7992. Doctoral Dissertation. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7993. Doctoral Dissertation. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.