

# DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

The Department of Electrical and Computer Engineering offers a Doctor of Philosophy degree in Electrical Engineering, a Master of Science degree in Electrical Engineering, a Master of Science degree in Computer Engineering, and administers a Master of Science degree in Advanced Materials Engineering.

- M.S. in Electrical Engineering (p. 1)
- M.S. in Computer Engineering (p. 2)
- M.S. in Advanced Materials Engineering (p. 4)
- Ph.D. in Electrical Engineering (p. 6)
- Integrated Bachelor's/Master's Program (p. 8)

## 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 and Control, Digital Signal Processing, Communications, and Electronic Materials and Devices. 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 60 on the Test of English as a Foreign Language (TOEFL) paper version, 79 on the 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.

#### A. Core course based on student's area of concentration from the list below: 3

Computer Engineering Concentration	
EE 5123	Computer Architecture
Systems and Control Concentration	
EE 5143	Linear Systems and Control
Digital Signal Processing Concentration	
EE 5163	Digital Signal Processing
Communications Concentration	
EE 5183	Foundations of Communication Theory
Electronic Materials and Devices Concentration	
EE 5693	Dielectric and Optoelectronic Devices
<b>B. At least one course from student's selected concentration</b>	
<b>C. At least one core course from outside the concentration</b>	
<b>D. Additional graduate electrical engineering courses<sup>1</sup></b>	
Must include 1 semester credit hour of EE 6991 Research Seminar	
<b>E. Other Electives (may be courses from outside electrical engineering)<sup>1</sup></b>	
<b>F. Master's Thesis (a minimum of 6 semester credit hours are required)</b>	
EE 6983	Master's Thesis

**Total Credit Hours 30**

<sup>1</sup> 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.

**A. Core course based on student's area of concentration from the list below:** 3

Computer Engineering Concentration		
EE 5123	Computer Architecture	
Systems and Control Concentration		
EE 5143	Linear Systems and Control	
Digital Signal Processing Concentration		
EE 5163	Digital Signal Processing	
Communications Concentration		
EE 5183	Foundations of Communication Theory	
Electronic Materials and Devices Concentration		
EE 5693	Dielectric and Optoelectronic Devices	

**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**<sup>1</sup> 9

Must include 1 semester credit hour of EE 6991 Research Seminar

**E. Other Electives (may be courses from outside electrical engineering)**<sup>1</sup> 6

**F. Master's Project (a minimum of 3 semester credit hours are required)** 3

EE 6943	Graduate Project	
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**Total Credit Hours** 33

<sup>1</sup> 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

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 and Control

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	Nonlinear 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 PWM Converters	3
EE 6343	Advanced Topics in Systems and Control	3
EE 7443	Nonlinear Control Systems	3

### Digital Signal Processing

EE 5153	Random Signals and Noise	3
EE 5163	Digital Signal Processing	3
EE 5263	Topics in Digital Signal Processing and Digital Filtering	3
EE 5353	Topics in Multimedia Signal Processing	3
EE 6363	Advanced Topics in Signal Processing	3

### Communications

EE 5153	Random Signals and Noise	3
EE 5183	Foundations of Communication Theory	3
EE 5283	Topics in Communication Systems	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

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

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 tenured-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.

## Master of Science Degree in Computer Engineering

The Master of Science degree in Computer Engineering is designed to offer students the opportunity to prepare for leadership roles in careers with industry, government, or educational institutions. Students enrolled in the M.S. degree program in Computer Engineering will have two options to obtain their degrees: (1) Thesis Option and (2) Non-Thesis

Option. 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 computer engineering or electrical engineering. A non-thesis option is offered 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 or computer engineering or in related fields for exceptional candidates
- A minimum grade point average of 3.0 in the last 60 semester credit hours of undergraduate studies
- Students whose native language is not English must achieve a minimum score of 60 on the Test of English as a Foreign Language (TOEFL) paper version, 79 on the 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 Computer Engineering Graduate Studies Committee. Applicants with an electrical or computer engineering background who wish to continue their education but do not intend to pursue the Master of Science degree in Computer 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.

The courses are divided into three groups as follows:

### Thesis Option

#### A. Select any two core courses from Group A 6

Group A. The following four core courses of this group form the basis for the program:

EE 5103	Engineering Programming
EE 5113	VLSI System Design
EE 5123	Computer Architecture
EE 5193	FPGA and HDL

#### B. Additional computer engineering courses from Group A or B (must include 1 semester credit hour of EE 6991 Research Seminar) <sup>1</sup> 12

Group B. Additional computer engineering courses:

CS 5103	Software Engineering
EE 5163	Digital Signal Processing
EE 5223	Topics in Digital Design (may be repeated when topic varies)
EE 5293	Topics in Microelectronics (may be repeated when topic varies)
EE 5323	Topics in VLSI Design (may be repeated when topic varies)
EE 5353	Topics in Multimedia Signal Processing (only Topic 1 and Topic 2)
EE 5423	Topics in Computer Architecture (may be repeated when topic varies)
EE 5453	Topics in Software Engineering (may be repeated when topic varies)

EE 5523	Introduction to Cloud Computing	
EE 6991	Research Seminar	
CPE 6953	Independent Study or CPE 6952 Independent Study or CPE 6951 Independent Study	
<b>C. Elective courses from Group A or B or C <sup>1</sup></b>		<b>6</b>
Group C. Free elective courses: any graduate-level electrical engineering course and the following courses		
CS 5113	Computer Graphics	
CS 5233	Artificial Intelligence	
CS 5363	Programming Languages and Compilers	
CS 5523	Operating Systems	
<b>D. Master's Thesis (a minimum of 6 semester credit hours)</b>		<b>6</b>
CPE 6983	Master's Thesis	
<b>Total Credit Hours</b>		<b>30</b>

<sup>1</sup> Chosen with approval of the Computer Engineering Graduate Program Committee.

### Non-Thesis Option

#### A. Select any two core courses from Group A 6

Group A. The following four core courses of this group form the basis for the program:

EE 5103	Engineering Programming
EE 5113	VLSI System Design
EE 5123	Computer Architecture
EE 5193	FPGA and HDL

#### B. Additional computer engineering courses from Group A or B (must include 1 semester credit hour of EE 6991 Research Seminar) <sup>1</sup> 15

Group B. Additional computer engineering courses:

CS 5103	Software Engineering
EE 5163	Digital Signal Processing
EE 5223	Topics in Digital Design (may be repeated when topic varies)
EE 5293	Topics in Microelectronics (may be repeated when topic varies)
EE 5323	Topics in VLSI Design (may be repeated when topic varies)
EE 5353	Topics in Multimedia Signal Processing (only Topic 1 and Topic 2)
EE 5423	Topics in Computer Architecture (may be repeated when topic varies)
EE 5453	Topics in Software Engineering (may be repeated when topic varies)
EE 5523	Introduction to Cloud Computing
EE 6991	Research Seminar
CPE 6953	Independent Study or CPE 6952 Independent Study or CPE 6951 Independent Study

#### C. Elective courses from Group A or B or C <sup>1</sup> 9

Group C. Free elective courses: any graduate-level electrical engineering course and the following courses

CS 5113	Computer Graphics
CS 5233	Artificial Intelligence

CS 5363	Programming Languages and Compilers	
CS 5523	Operating Systems	
<b>D. Master's Project (a minimum of 3 semester credit hours)</b>		<b>3</b>
CPE 6943	Graduate Project	
<b>Total Credit Hours</b>		<b>33</b>

<sup>1</sup> Chosen with approval of the Computer Engineering Graduate Program Committee.

One (1) credit hour of EE 6991 Research Seminar is required for both the thesis and non-thesis options and up to two (2) credit hours of EE 6991 can be included. No more than three (3) credit hours of independent study can be included.

Degree plans must be consistent with the guidelines established by the Computer 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 tenured-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.

## 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 (UTSA) is an interdisciplinary graduate degree program offered by the 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 and Computer 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 in taking multidisciplinary courses from the College of Engineering and Integrated Design and other colleges at UTSA to enhance students' interdisciplinary research potentials as well as their technical leadership and entrepreneurship skills. The affiliated program faculty consists of UTSA graduate faculty who offers MatE core/concentration courses or serves on MatE Program/Supervising Committees during the current or previous catalog period. Each MatE program faculty is actively engaged in interdisciplinary research/education and brings to this program extensive and a 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 two concentrations are offered:

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

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 from the Management of Technology program, 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 60 on the Test of English as a Foreign Language (TOEFL) paper version, 79 on the 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 courses (at least 6 credits from the chosen concentration) in Group B, must be taken to satisfy the depth and the breadth requirement. Up to 6 credits may be taken from courses in Group C, including courses from outside of the College of Engineering 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 Directed Research in Advanced Materials Engineering, MOT 6971 or MOT 6973 Special Problems 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.

#### 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

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 concentrations:

##### 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

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

#### 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 and Program 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 courses (at least 9 credits from the chosen concentration) in Group B must be taken to satisfy the depth and the breadth requirement. Up to 9 credits may be taken from courses in Group C, including courses from out of the College of Engineering 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 Directed Research in Advanced Materials Engineering, MOT 6971 or MOT 6973 Special Problems 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.

#### 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

MATE 5113	Functions, Evaluations and Synthesis Technology of Advanced Materials	
MOT 5163	Management of Technology	
<b>B. Concentration specific courses from Group B</b>		<b>12</b>
Group B. Concentration specific courses - at least 9 credits must be from the chosen concentration		
<b>Concentration I: Multifunctional Electronic, Dielectric, Photonic and Magnetic Materials</b>		
EE 5403	Advanced Dielectric and Optoelectronic Engineering Laboratory	
EE 5503	Introduction to Nanoelectronics	
EE 5693	Dielectric and Optoelectronic Devices	
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	
<b>Concentration II: Multifunctional Biomedical Materials</b>		
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 6733Microfabrication and Application	
MATE 5523	Biosensors: Fundamentals and Applications or BME 6753Biosensors: 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	
<b>C. Prescribed Electives from Group C</b>		<b>9</b>
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 and Program 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	
<b>D. Master's Project (a minimum of 3 semester credit hours)</b>		<b>3</b>
MATE 6943	Master's Project	
<b>Total Credit Hours</b>		<b>33</b>

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 holding an oral comprehensive exam with the supervising committee. The committee consists of minimum 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.

## Doctor of Philosophy Degree in Electrical Engineering

The Department of Electrical and Computer Engineering offers advanced coursework integrated with research leading to the Doctor of Philosophy degree in Electrical Engineering. The program has emphases in five concentrations: Computer Engineering, Systems and Control, Digital Signal Processing, Communications, and Electronic Materials and Devices. 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 master's degree before being granted admission to the program. Only exceptional, well prepared, and highly competitive candidates should apply to enter the Ph.D. program directly upon receiving a bachelor's degree.
- 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 program must have a grade point average of 3.3 or better in the last 60 semester credit hours of undergraduate coursework in electrical engineering.
- Applicants who would like to transfer in 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 60 on the Test of English as a Foreign Language (TOEFL) paper version, 79 on the 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.

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. Admission is competitive. Satisfying these requirements does not guarantee admission.

## Degree Requirements and Program of Study

The degree requires 81 semester credit hours beyond the bachelor's degree or 54 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:

EE 5123	Computer Architecture (Computer Engineering)	3
EE 5143	Linear Systems and Control (Systems and Control)	3
EE 5163	Digital Signal Processing (Digital Signal Processing)	3
EE 5183	Foundations of Communication Theory (Communications)	3
EE 5693	Dielectric and Optoelectronic Devices (Electronic Materials and Devices)	3

## 81 Semester Credit Hours beyond the Bachelor's Degree

The course requirements for 81 credit hours include 45 technical course credits, 18 research credits identified as EE 7951, EE 7952, and EE 7953 Doctoral Research and 18 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 7931-3 Doctoral Research Seminar is required, and up to a total of 3 credit hours of EE 7931-3 Doctoral Research Seminar and EE 6951-3 Independent Study combined. Up to six credit hours may be taken from other graduate courses outside electrical engineering with approval of the Electrical Engineering Graduate Program Committee.

### 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 and Control Concentration	
EE 5143	Linear Systems and Control
Digital Signal Processing Concentration	
EE 5163	Digital Signal Processing
Communications Concentration	
EE 5183	Foundations of Communication Theory
Electronic Materials and Devices Concentration	
EE 5693	Dielectric and Optoelectronic Devices

### B. Graduate elective courses 39

At least one credit hour of EE 7931-3 Doctoral Research Seminar is required and up to 3 credit hours total are allowed including EE 7931-3 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. Research credits identified as EE 7951, EE 7952, and EE 7953 Doctoral Research 18

### D. Dissertation credits identified as EE 7991, EE 7992, and EE 7993 Doctoral Dissertation 18

### Total Credit Hours 81

## 54 Semester Credit Hours beyond the Master's Degree

The course requirements for 54 credit hours include 18 technical course credits, 18 research credits identified as EE 7951, EE 7952, and EE 7953 Doctoral Research and 18 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 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 7931-3 Doctoral Research Seminar is required, and up to a total of 3 credit hours of EE 7931-3 Doctoral Research Seminar and EE 6951-3 Independent Study combined are allowed, including those earned towards 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.

### 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 and Control Concentration	

EE 5143	Linear Systems and Control	
Digital Signal Processing Concentration		
EE 5163	Digital Signal Processing	
Communications Concentration		
EE 5183	Foundations of Communication Theory	
Electronic Materials and Devices Concentration		
EE 5693	Dielectric and Optoelectronic Devices	
<b>B. Graduate elective courses</b>		<b>12</b>
At least one credit hour of EE 7931-3 Doctoral Research Seminar is required, and up to a total of 3 credit hours of EE 7931-3 Doctoral Research Seminar and EE 6951-3 Independent Study combined are allowed, including those earned towards the Master's degree.		
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.		
<b>C. Research credits identified as EE 7951, EE 7952, and EE 7953</b>		<b>18</b>
<b>Doctoral Research</b>		
<b>D. Dissertation credits identified as EE 7991, EE 7992, and EE 7993</b>		<b>18</b>
<b>Doctoral Dissertation</b>		
<b>Total Credit Hours</b>		<b>54</b>

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 UTSA 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 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 field. Students may select a concentration with the approval of the faculty advisor. The exam is offered at the beginning of the Spring and Fall

semesters. In order to take the written examination, students must have taken two core courses with a grade point average (GPA) of no less than 3.5. No courses with a GPA of less than 3.0 can be counted to satisfy the knowledge competency. An advanced graduate course (non-laboratory intensive) with a specified core course as 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 at 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.

## 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 and Computer Engineering is designed to make 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 the 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 UTSA 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) Non-Thesis 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.

## 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.

The certificate is administered by the College of Engineering in conjunction with the College of Business and the College of Sciences. The course requirements for each program focus may be found under the College of Engineering, the Department of Computer Science (<http://catalog.utsa.edu/graduate/sciences/computerscience/#certificatestext>), and the Department of Information Systems and Cyber Security (<http://catalog.utsa.edu/graduate/business/informationssystemscybersecurity/#certificatestext>).

## Certificate Requirements

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

### 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 instructor from each college contributes to the subjects outlined in the course syllabus.

### B. Track Electives 6

Select two courses from any of the following tracks:

#### 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 Unix and Network 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)	
<b>C. Capstone Project</b>		<b>3</b>
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 6943	Graduate Project	
EE 6953	Independent Study	
EE 7933	Doctoral Research Seminar	
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	
<b>Total Credit Hours</b>		<b>12</b>

Student may take cloud course(s) not listed above for credit with prior approval from 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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

### **MATE 5223. Structure-Chemistry-Property Relations in Materials Science and Engineering. (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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

### **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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**MATE 6941. Master's Project. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**MATE 6942. Master's Project. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**MATE 6943. Master's Project. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**MATE 6951. Directed Research in Advanced Materials Engineering. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**MATE 6952. Directed Research in Advanced Materials Engineering. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**MATE 6953. Directed Research in Advanced Materials Engineering. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**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). Differential Tuition: \$55.

**MATE 6981. Master's Thesis Research. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**MATE 6982. Master's Thesis Research. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**MATE 6983. Master's Thesis Research. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

## Computer Engineering (CPE) Courses

**CPE 6941. Graduate Project. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**CPE 6942. Graduate Project. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**CPE 6943. Graduate Project. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**CPE 6951. Independent Study. (0-0) 1 Credit Hour.**

Prerequisites: Graduate standing and permission in writing (form available) from 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. Differential Tuition: \$55.

**CPE 6952. Independent Study. (0-0) 2 Credit Hours.**

Prerequisites: Graduate standing and permission in writing (form available) from 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. Differential Tuition: \$110.

**CPE 6953. Independent Study. (0-0) 3 Credit Hours.**

Prerequisites: Graduate standing and permission in writing (form available) from 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. Differential Tuition: \$165.

**CPE 6981. Master's Thesis. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**CPE 6982. Master's Thesis. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**CPE 6983. Master's Thesis. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

## Electrical Engineering (EE) Courses

**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. Differential Tuition: \$165.

**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.) Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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.) Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. 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, 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 system. Control schemes include NI DAQ based control and FPGA based control.5: Power Electronics. Switching power converter operation and design; modeling of power converters; power components including power semiconductor devices, inductors, and transformers; control of power converters; select power converter topology for applications such as renewable energy, electric transportation, and telecommunications. Learning objectives: Analyze basic operation of switching power converters; simulate 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. May be repeated for credit as topics vary. Differential Tuition: \$165.

**EE 5263. Topics in Digital Signal Processing and Digital Filtering. (3-0) 3 Credit Hours.**

Prerequisite: EE 5153 or EE 5163, or consent of instructor. Topics may include the following: Topic 1: Nonlinear Filters. Order statistic filters, morphological filters, stack/Boolean filters, and other related topics. Topic 2: Detection and Estimation Theory. Minimum variance unbiased estimation, Cramer-Rao low bound, maximum likelihood estimation, Bayesian estimation, Neyman-Pearson detector, Bayesian detector, matched filter, Generalized Likelihood Ratio Test. Topic 3: Orthogonal Transforms, Wavelets and Fractals with Applications. Fast orthogonal transform (Cosine, Sine, Hartley, Haar, Slant, Short-time Fourier and Gabor and Walsh), subband decomposition, fractals, fractal dimension, iterated function systems, denoising and others. Topic 4: Wavelet Transforms and Applications. Subband decompositions; wavelets and wavelet packets: construction, properties, decomposition and reconstruction, multiresolution analyses; image and video international compression standards, signal and image denoising; steganography, and watermarking. Topic 5: Signal Processing for Wireless Systems. Usage of transforms for the analysis and design of wireless systems. FIR and IIR filter design and adaptive signal processing for wireless systems. May be repeated for credit as topics vary. Differential Tuition: \$165.

**EE 5283. Topics in Communication Systems. (3-0) 3 Credit Hours.**

Prerequisite: Graduate standing or consent of instructor. May be repeated for credit as topics vary. 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, . 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: Engineering Optimization. Convex sets and functions. Convex optimization problems: Linear programming, quadratic programming, geometric programming, semidefinite programming. Optimality conditions. Lagrangian duality. Optimization algorithms: Gradient methods, Newton's method, Lagrange multiplier methods, interior point methods, subgradient methods. Applications in different areas of Electrical Engineering, such as Communications and Networking (power control in cellular networks, optimal transceiver design for multiaccess communication, optimal routing and optimal network flow), Signal Processing (least squares problems, regression models, sparsity-promoting regularizations), and Power Systems (economic dispatch, optimal power flow, electricity markets). 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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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, feature 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. Differential Tuition: \$165.

**EE 5373. Wireless Communication. (3-0) 3 Credit Hours.**

Prerequisite: Graduate standing or consent of instructor. This course offers in-depth study of wireless communication systems at the physical layer, propagation modeling for wireless systems, modulation schemes used for wireless channels, diversity techniques and multiple antenna systems, and multiple access schemes used in wireless systems. Differential Tuition: \$165.

**EE 5403. Advanced Dielectric and Optoelectronic Engineering Laboratory. (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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**EE 5453. Topics in Software Engineering. (3-0) 3 Credit Hours.**

Prerequisite: EE 5123 or consent of instructor. 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 project. Topic 2: Embedded Software Systems Design. 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. May be repeated for credit as topics vary. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**EE 5573. Machine Learning. (3-0) 3 Credit Hours.**

Prerequisite: EE 5153. Introduction to concepts of training, testing, and cross-validation. Probability and statistical inference: conditional probability and expectation, maximum likelihood estimation and MAP estimation. Linear and nonlinear supervised methods in regression and classification including linear discriminant analysis, logistic regression, support vector machines, ridge regression, LASSO, elastic net, and neural networks. Unsupervised methods including clustering and dimensionality reduction. Mathematics of machine learning: vector spaces, linear algebra, convex optimization, and stochastic gradient descent. Differential Tuition: \$165.

**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, BCH 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. Differential Tuition: \$165.

**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 piezoelectric, piezoelectric, ferroelectric and various electronic sensors and actuators. May be repeated for credit as topics vary. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.



**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$165.

**EE 6243. Modeling and Control of Three-Phase PWM Converters. (3-0) 3 Credit Hours.**

Develop understanding of power conversion principles in three-phase 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. Different Tuition: \$165.

**EE 6343. Advanced Topics in Systems and Control. (3-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**EE 6363. Advanced Topics in Signal Processing. (3-0) 3 Credit Hours.**

Prerequisites: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the signal processing area. May be repeated for credit as topics vary. Differential Tuition: \$165.

**EE 6383. Advanced Topics in Communications. (3-0) 3 Credit Hours.**

Prerequisites: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the communications area. May be repeated for credit as topics vary. Differential Tuition: \$165.

**EE 6493. Advanced Topics in Electronic Materials and Devices. (2-3) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**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). Differential Tuition: \$55.

**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). Differential Tuition: \$110.

**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). Differential Tuition: \$165.

**EE 6941. Graduate Project. (0-0) 1 Credit Hour.**

Prerequisites: 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.) Differential Tuition: \$55.

**EE 6942. Graduate Project. (0-0) 2 Credit Hours.**

Prerequisites: 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.) Differential Tuition: \$110.

**EE 6943. Graduate Project. (0-0) 3 Credit Hours.**

Prerequisites: 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.) Differential Tuition: \$165.

**EE 6951. Independent Study. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**EE 6952. Independent Study. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**EE 6953. Independent Study. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**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). Differential Tuition: \$55.

**EE 6971. Special Problems. (1-0) 1 Credit Hour.**

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. Differential Tuition: \$55.

**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. Differential Tuition: \$165.

**EE 6981. Master's Thesis. (0-0) 1 Credit Hour.**

Prerequisites: 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. Differential Tuition: \$55.

**EE 6982. Master's Thesis. (0-0) 2 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$110.

**EE 6983. Master's Thesis. (0-0) 3 Credit Hours.**

Prerequisites: 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. Differential Tuition: \$165.

**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. Differential Tuition: \$55.

**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. Differential Tuition: \$165.

**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. Differential Tuition: \$55.

**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. Differential Tuition: \$110.

**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. Differential Tuition: \$165.

**EE 7951. Doctoral Research. (0-0) 1 Credit Hour.**

Prerequisites: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. Differential Tuition: \$55.

**EE 7952. Doctoral Research. (0-0) 2 Credit Hours.**

Prerequisites: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. Differential Tuition: \$110.

**EE 7953. Doctoral Research. (0-0) 3 Credit Hours.**

Prerequisites: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. Differential Tuition: \$165.

**EE 7991. Doctoral Dissertation. (0-0) 1 Credit Hour.**

Prerequisites: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. Differential Tuition: \$55.

**EE 7992. Doctoral Dissertation. (0-0) 2 Credit Hours.**

Prerequisites: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. Differential Tuition: \$110.

**EE 7993. Doctoral Dissertation. (0-0) 3 Credit Hours.**

Prerequisites: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. Differential Tuition: \$165.