Electrical and Computer Engineering (EECE)

Chairperson: Majeed Hayat, Ph.D.
Electrical and Computer Engineering Graduate Programs website (https://www.marquette.edu/grad/programs-electrical-computer-engineering.php)

Degrees Offered
Master of Science; Doctor of Philosophy; Certificates

Mission Statement
The Department of Electrical and Computer Engineering embraces the missions of Marquette University and its College of Engineering. The mission of the Department of Electrical and Computer Engineering is to offer its students high quality, up-to-date, nationally-recognized programs in electrical and computer engineering that prepare them for successful careers. This success is marked by a commitment to lifelong learning and a deep concern for the impact of their work on others, research that advances the frontiers of technical and scientific knowledge and service to professional and civic communities.

Program Descriptions
The master of science and doctor of philosophy degree programs are designed to provide graduate students with both broad fundamental knowledge and up-to-date information on current and emerging technologies. Students may enroll on either a full-time or part-time basis (with the exception of the one-year residency requirement for doctoral students). Doctoral students and research-oriented master's students engage in research activities under the close supervision of their advisers, gradually learning to become independent researchers. Their projects often are supported by government and industry grants. Courses and research activities make significant use of the department's extensive laboratory and computer facilities. Graduates find employment in industry, research facilities, government and academia.

The Department also offers two graduate certificates in electrical engineering and computer engineering, designed for practicing professionals. Students typically enroll on a part-time basis. The certificate in renewable energy technology and integration (RETI) is intended to develop graduates with the capabilities required to solve complex renewable-energy problems in a variety of application domains. The RETI certificate will offer students the opportunity to achieve a greater technical understanding of the elements of renewable-energy development including sustainable-energy sources, microgrids, power conversion, and energy policy. Graduates of the RETI program are likely to find positions in a wide range of organizations including governmental agencies, electric power generating industries, consulting engineering companies, manufacturing employers, and other services. The certificate in machine learning for engineering applications (MLRN) will offer students the opportunity to achieve a greater technical understanding of the elements of machine learning, which includes algorithms, intelligent systems, neural networks, pattern recognition, and deep learning. It will allow engineers to (1) apply the fundamentals of machine learning to solve engineering problems in their organization and (2) supplement on-the-job training often employed in industry to develop this skillset. Graduates of the MLRN program may find positions in a wide range of organizations including industry and governmental agencies, data-science and data-analytics businesses, AI industries, consulting engineering companies, and other services.

Prerequisites for Admission
Graduates of accredited colleges or universities with bachelor's degree in electrical engineering, computer engineering or equivalent are eligible for admission. Only those applicants whose undergraduate records show promise of success in graduate study are admitted. To qualify for admission, applicants must have, as a minimum, approximately a B average in their total post-secondary school education.

A master of science degree or equivalent in an appropriate field of study is required for admission to the doctoral program. Applicants with bachelor's degrees must first be admitted to and successfully complete the master of science degree program and may then continue into the doctoral program.

Application Requirements
Applicants must submit, directly to the Graduate School:

1. A completed application form and fee online (http://marquette.edu/grad/future_apply.shtml).
2. Copies of all college/university transcripts except Marquette.¹
3. Three letters of recommendation.
5. GRE test scores (General Test only).
6. (For international applicants only) a TOEFL score or other acceptable proof of English proficiency.

¹ Upon admission, final official transcripts from all previously attended colleges/universities, with certified English translations if original language is not English, must be submitted to the Graduate School within the first five weeks of the term of admission or a hold preventing registration for future terms will be placed on the student's record.
General Information

All admitted students are required to obtain and read the department’s Graduate Student Handbook (http://www.marquette.edu/engineering/electrical_computer/documents/gradhandbook2010.pdf), which contains complete details about the electrical and computer engineering programs and additional departmental degrees. This handbook is available through the Electrical and Computer Engineering Office, (414) 288-6820 and on the department’s graduate programs website (http://www.marquette.edu/engineering/electrical_computer/grad.shtml).

Electrical and Computer Engineering Master’s Requirements

The EECE department offers two options for earning a master's degree: a thesis option (Plan A) and a non-thesis/course work option (Plan B). By the end of the first term of full-time studies, all master's students are required to meet with their academic adviser and together complete a Master's Program Planning Form. This planning form will identify the chosen option (Plan A or B) as well as the proposed set of courses for their program of study. The program of study must be approved by the adviser and the EECE director of graduate studies.

Students choose one or more from the list of the EECE Department focus areas: Signal Processing, Communications and Controls (Signal Processing, Controls, or Communications); Power and Energy Systems; Electronic Devices and Microsystems; and Computer Engineering (Computer Vision and Image Processing, Embedded Systems and Internet of Things (IoT), or Machine Learning and Algorithms).

Thesis Option (Plan A)

For Plan A, students complete 24 credit hours of course work and 6 credit hours of EECE 6999 Master’s Thesis for a total of 30 credit hours. All full-time students are required to participate in EECE 6952 Department Colloquium (0 credits) each semester. Course selections are determined in consultation with the adviser and depend on the focus area chosen.

- At least 18 of the 24 credits hours of course work must be taken in EECE.
- At least 12 credit hours (exclusive of thesis) must be taken strictly at the graduate level (6000 or 8000-level).
- Students must successfully complete and defend a research thesis under the guidance of their faculty advisers and thesis committee members.

Non-Thesis/Course Work Option (Plan B)

For Plan B, students complete a total of 30 credit hours of course work. All full-time students are required to participate in EECE 6952 Department Colloquium (0 credits) each semester. Course selections are determined in consultation with the adviser and depend on the focus area chosen.

- At least 21 credit hours must be in EECE.
- At least 18 credits of the total program course work and at least 12 credits of the EECE course work must be taken strictly at the graduate level (6000 or 8000-level).
- Students must successfully pass the master of science comprehensive written examination, given in fall and spring term, prior to graduation. The exam covers material from the selected focus area courses.

Signal Processing, Communications and Controls

Core Courses (9 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECE 6010</td>
<td>Advanced Engineering Mathematics</td>
<td>3</td>
</tr>
<tr>
<td>EECE 6020</td>
<td>Probability and Random Processes in Engineering</td>
<td>3</td>
</tr>
<tr>
<td>Choose 1 of 3 area-specific courses:</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>EECE 5510</td>
<td>Digital Signal Processing</td>
<td></td>
</tr>
<tr>
<td>EECE 5560</td>
<td>Introduction to Communication Systems</td>
<td></td>
</tr>
<tr>
<td>EECE 5310</td>
<td>Control Systems</td>
<td></td>
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</tbody>
</table>

Elective Core Course Options (9 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECE 5320</td>
<td>Digital Control Systems</td>
<td></td>
</tr>
<tr>
<td>EECE 5390</td>
<td>Developments in Control</td>
<td></td>
</tr>
<tr>
<td>EECE 5550</td>
<td>Developments in Signal Processing</td>
<td></td>
</tr>
<tr>
<td>EECE 5565</td>
<td>Optical Fiber Communications</td>
<td></td>
</tr>
<tr>
<td>EECE 5570</td>
<td>Wireless Communications</td>
<td></td>
</tr>
<tr>
<td>EECE 6310</td>
<td>Modern Control Theory</td>
<td></td>
</tr>
<tr>
<td>EECE 6320</td>
<td>Optimal Control</td>
<td></td>
</tr>
<tr>
<td>EECE 6330</td>
<td>Nonlinear and Adaptive Control</td>
<td></td>
</tr>
<tr>
<td>EECE 6340</td>
<td>Stochastic Systems Estimation and Control</td>
<td></td>
</tr>
</tbody>
</table>
EECE 6510  Optimal and Adaptive Digital Signal Processing
EECE 6520  Digital Processing of Speech Signals
EECE 6530  Chaos and Nonlinear Signal Processing
EECE 6540  Advanced Digital Image Processing
EECE 6560  Information and Coding Theory
EECE 6931  Topics in Electrical and Computer Engineering (Digital Communications)
EECE 6931  Topics in Electrical and Computer Engineering (Detection and Estimation)
EECE 6931  Topics in Electrical and Computer Engineering (Machine Learning for Image Processing)

Elective Courses  6
Selected graduate-level courses in EECE, biomedical engineering, computer science, mathematics as approved by adviser.
EECE 6952  Department Colloquium (required each semester for all full-time students)  0
Plan A or Plan B requirements, as listed above.  6
Total Credit Hours  30

Power and Energy Systems

Core Courses (9 credits)
EECE 5210  Design and Analysis of Electric Motor-Drive Systems  3
EECE 5220  Power Electronics for Renewable Energy Systems  3
Choose 1 of 2 area-specific courses:  3
EECE 5240  Protection and Monitoring of Electric Energy Systems
EECE 5250  Transients in Electric Energy Systems and Devices

Elective Core Course Options  9
EECE 5230  Renewable and Legacy Electric Energy Systems Analysis
EECE 5290  Developments in Energy and Power
EECE 6210  Advanced Electric Machines and Drives
EECE 6220  Advanced Concepts in the Design and Modeling of Electric Machines and Drives
EECE 6230  Finite Element Analysis
EECE 6932  Advanced Topics in Electrical and Computer Engineering (Advanced Electrical Machine Design)
EECE 6932  Advanced Topics in Electrical and Computer Engineering (Advanced Power Electronics)
EECE 6932  Advanced Topics in Electrical and Computer Engineering (Vector Control)

Elective Courses  6
EECE 5320  Digital Control Systems
EECE 6010  Advanced Engineering Mathematics
EECE 6020  Probability and Random Processes in Engineering
EECE 6310  Modern Control Theory
EECE 6320  Optimal Control
EECE 6330  Nonlinear and Adaptive Control

Selected graduate-level courses in EECE, biomedical engineering, computer science, mathematics as approved by adviser.
EECE 6952  Department Colloquium (required each semester for all full-time students)  0
Plan A or Plan B requirements, as listed above.  6
Total Credit Hours  30

Electronic Devices and Microsystems

Core Courses (Choose 9 total credits)  9
EECE 5110  Microwave Engineering
or EECE 6110  Advanced Electromagnetic Fields
or EECE 6120  Electromagnetic Theory
EECE 5430  Physical Principles of Solid State Devices
EECE 6010  Advanced Engineering Mathematics
EECE 6932  Advanced Topics in Electrical and Computer Engineering (Introduction to MEMS)

Elective Core Course Options  9
EECE 5130  Antenna Theory and Design
### Electrical and Computer Engineering (EECE)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>EECE 5460</td>
<td>Sensor Devices: Theory, Design, and Applications</td>
</tr>
<tr>
<td>EECE 6130</td>
<td>Numerical Techniques in Electromagnetics</td>
</tr>
<tr>
<td>EECE 6430</td>
<td>Microelectromechanical Systems and Sensors</td>
</tr>
<tr>
<td>EECE 6931</td>
<td>Topics in Electrical and Computer Engineering (Introduction to Device Fabrication)</td>
</tr>
<tr>
<td>EECE 6931</td>
<td>Topics in Electrical and Computer Engineering (MEMS and Nanotechnology)</td>
</tr>
</tbody>
</table>

**Elective Courses**

- Selected graduate-level courses in EECE, thermodynamics, quantum mechanics, materials, finite element methods, mechanical engineering, biomedical engineering, mathematics as approved by adviser.

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<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>EECE 6952</td>
<td>Department Colloquium (required each semester for all full-time students)</td>
</tr>
</tbody>
</table>

Plan A or Plan B requirements, as listed above. 6

**Total Credit Hours** 30

### Computer Engineering

**Core Courses (Choose 9 total credits)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>EECE 5650</td>
<td>Introduction to Algorithms</td>
</tr>
<tr>
<td>EECE 6810</td>
<td>Algorithm Analysis and Applications</td>
</tr>
<tr>
<td>EECE 6822</td>
<td>Machine Learning</td>
</tr>
</tbody>
</table>

- One 3-credit selected mathematics course

**Elective Core Course Options**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>EECE 5510</td>
<td>Digital Signal Processing</td>
</tr>
<tr>
<td>EECE 5850</td>
<td>Introduction to Intelligent Systems</td>
</tr>
<tr>
<td>EECE 5860</td>
<td>Introduction to Neural Networks and Fuzzy Systems</td>
</tr>
<tr>
<td>EECE 6540</td>
<td>Advanced Digital Image Processing</td>
</tr>
<tr>
<td>EECE 6840</td>
<td>Neural Networks and Neural Computing</td>
</tr>
<tr>
<td>EECE 6931</td>
<td>Topics in Electrical and Computer Engineering (Machine Learning and Medical Image Analysis)</td>
</tr>
<tr>
<td>EECE 6932</td>
<td>Advanced Topics in Electrical and Computer Engineering (Advanced Signal Processing)</td>
</tr>
</tbody>
</table>

- One 3-credit selected mathematics course

**Embedded Systems and Internet of Things (IoT):**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>EECE 5490</td>
<td>Developments in Devices</td>
</tr>
<tr>
<td>EECE 5510</td>
<td>Digital Signal Processing</td>
</tr>
<tr>
<td>EECE 5710</td>
<td>Computer Hardware</td>
</tr>
<tr>
<td>EECE 5730</td>
<td>Computer Architecture</td>
</tr>
<tr>
<td>EECE 5740</td>
<td>Advanced VHDL and FPGA Design</td>
</tr>
<tr>
<td>EECE 5850</td>
<td>Introduction to Intelligent Systems</td>
</tr>
<tr>
<td>EECE 6932</td>
<td>Advanced Topics in Electrical and Computer Engineering (Advanced Signal Processing)</td>
</tr>
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</table>

- One 3-credit selected mathematics course

**Machine Learning and Algorithms:**

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>EECE 5690</td>
<td>Developments in Computer Software</td>
</tr>
<tr>
<td>EECE 5850</td>
<td>Introduction to Intelligent Systems</td>
</tr>
<tr>
<td>EECE 5860</td>
<td>Introduction to Neural Networks and Fuzzy Systems</td>
</tr>
<tr>
<td>EECE 5870</td>
<td>Evolutionary Computation</td>
</tr>
<tr>
<td>EECE 6830</td>
<td>Pattern Recognition</td>
</tr>
<tr>
<td>EECE 6840</td>
<td>Neural Networks and Neural Computing</td>
</tr>
<tr>
<td>EECE 6931</td>
<td>Topics in Electrical and Computer Engineering (Machine Learning and Medical Image Analysis)</td>
</tr>
</tbody>
</table>

- One 3-credit selected mathematics course

**Elective Courses**

- Selected graduate-level courses in EECE, biomedical engineering, computer science, mathematics as approved by adviser.

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>EECE 6952</td>
<td>Department Colloquium (required each semester for all full-time students)</td>
</tr>
</tbody>
</table>

Plan A or Plan B requirements, as listed above. 6

**Total Credit Hours** 30
Accelerated Bachelor’s–Master’s Degree Program

The EECE Department offers an accelerated degree program where eligible students may obtain both a bachelor's degree and a master of science degree in electrical and computer engineering in five years.

- Students with a GPA of 3.500 or better in their mathematics, science and engineering courses are eligible to apply to this program in their junior year.
- This program is available to undergraduate students in electrical and computer engineering or in physics.
- Students wishing to participate in the five-year program must apply and be admitted to the program before their senior year.

Electrical and Computer Engineering Doctoral Requirements

Students entering the EECE doctoral program with a master's degree must take 24 post-master's credit hours of course work, plus an additional 12 dissertation credits in EECE 8999 Doctoral Dissertation, for a total of 36 credit hours. At least 18 of the 24 credit hours of course work must be taken in EECE. A master's degree is considered to be the equivalent of 24 credit hours of course work; the doctoral degree's course work requirement is the equivalent of 48 credits beyond the bachelor's degree, exclusive of dissertation credits.

Students entering the EECE doctoral program with a bachelor's degree must take 48 post-baccalaureate credit hours of course work, plus an additional 12 dissertation credits in EECE 8999 Doctoral Dissertation, for a total of 60 credit hours. Students entering the program with a bachelor's degree must first complete the requirements for the master of science degree.

Students choose one or more from the list of the EECE Department focus areas: Signal Processing, Communications and Controls (Signal Processing, Controls, or Communications); Power and Energy Systems; Electronic Devices and Microsystems; and Computer Engineering (Computer Vision and Image Processing, Embedded Systems and Internet of Things (IoT), or Machine Learning and Algorithms).

By the end of the first year of full-time studies, all doctoral students are required to meet with their academic adviser and together complete a Doctoral Program Planning Form. Completion of the Doctoral Program Planning Form must form a cohesive overall plan of study, including course requirements as determined by the selected focus area.

Doctoral students are also required to complete the doctoral written qualifying examination (WQE) by the end of the third semester of study. The WQE is administered twice per year. Following successful completion of the WQE, students become doctoral candidates and move forward to pursue their dissertation research.

The doctoral dissertation process requires the declaration of a faculty dissertation committee and a presentation of an oral proposal to the committee. Students write a dissertation of original, independent research, successfully defend the dissertation, and submit an approved dissertation. The dissertation defense is a public defense and must be scheduled in advance.

Post-master's Program Requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>EECE 6952</td>
<td>24</td>
</tr>
<tr>
<td>EECE 8999</td>
<td>12</td>
</tr>
<tr>
<td>Total Credit Hours</td>
<td>36</td>
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</tbody>
</table>

Post-baccalaureate Program Requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECE 6952</td>
<td>48</td>
</tr>
<tr>
<td>EECE 8999</td>
<td>12</td>
</tr>
<tr>
<td>Total Credit Hours</td>
<td>60</td>
</tr>
</tbody>
</table>

The Department of Electrical and Computer Engineering offers a certificate in machine learning for engineering applications and a certificate in renewable energy technology and integration. Certificate requirements can be found in the Graduate Certificates section (http://bulletin.marquette.edu/grad/programs/engineering/engineeringcertificates/#text).
Courses

EECE 5015. Advanced Electrical Engineering Laboratory. 3 cr. hrs.
Project-based laboratory experience in the design, assembly and testing of advanced electronic and electrical systems. Course content announced prior to each term. Students may enroll in the course more than once as the content of the course changes. Possible topics for the advanced laboratory experience include, but are not limited to: advanced electromagnetic system design, optical and high frequency electronics, nonlinear control systems, motor control circuits and systems, power electronics, communications circuits, integrated microelectronic circuit design and fabrication (VLSI), advanced analog system design, advanced digital system design, microprocessor system-level design. Instruction and use of the appropriate test and measurement tools for design, assembly and testing of systems. Two hrs. lec., 2 hrs. lab. Prereq: Cons. of instr.

EECE 5090. Developments in Electronics. 1-3 cr. hrs.
Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Possible topics include laser electronics, optoelectronics and photonics, RF circuit design, SOC design. Prereq: Cons. of instr. or grad. stndg.

EECE 5110. Microwave Engineering. 3 cr. hrs.
Studies the fundamentals of microwave engineering. After a review of transmission line theory and the Smith chart, the scattering parameters are developed and used to characterize and design a variety of devices including power dividers/directional couplers, filters, amplifiers, oscillators and mixers. Also introduces and develops receiver architectures and system noise. Prereq: ELEN 3110 or equivalent.

EECE 5130. Antenna Theory and Design. 3 cr. hrs.
Design and use of antennas of varying types, including wire, broadband, horn, and reflector antennas in transmitting and receiving applications. The application and design of antenna arrays, and an introduction to diffraction theory.

EECE 5150. Applied Finite Elements in Electromagnetics. 3 cr. hrs.
Introduction to finite element (FE) analysis as applied to linear and static electromagnetic field problems. Review of basic field formulations using Maxwell’s electromagnetic field equations, solution of boundary value problems using the finite difference methods, FE formulations, assembly of elemental and global matrices, pre-processing, post-processing. Application of the FE method using one-dimensional and two-dimensional elements, magnetostatic and electrostatic analysis, and the use of commercially available software packages.

EECE 5190. Developments in Electromagnetics. 1-3 cr. hrs.
Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Possible topics include laser electronics, optoelectronics and photonics, RF circuit design, SOC design. Prereq: Cons. of instr. or grad. stndg.

EECE 5210. Design and Analysis of Electric Motor-Drive Systems. 3 cr. hrs.
Principles of design of AC and DC electric machines, in particular design of electric motors in power electronically controlled adjustable speed drives, torque and power to volume analysis under constant volts per hertz torque-speed control. Covers design of AC induction, synchronous, universal and DC conventional as well as brushless DC motors, and low horsepower motors in adjustable speed drives. Covers effects of space and time harmonics on motor design and performance are covered including harmonic abatement for control of torque pulsation. Use of modern modeling techniques throughout.


EECE 5230. Renewable and Legacy Electric Energy Systems Analysis. 3 cr. hrs.
Elements of renewable and legacy electric power systems; fundamental concepts and techniques for design and analysis; per unit system; load flow; economic dispatch; smart grids and load management; steady state and transient power system stability.

EECE 5240. Protection and Monitoring of Electric Energy Systems. 3 cr. hrs.
Principles of design of relay and sensor systems for detection of faulty operating conditions in electric generators, transformers, power transmission lines, motors and other loads in power systems. Symmetrical components, balanced and unbalanced faults including single and multiple unbalances. Design and hierarchical coordination of protection systems for interconnected generation, transmission and distribution facilities in power systems, which includes integrated generator-transformer-busbar-transmission line-load protection and analysis of operation under fault conditions.

EECE 5250. Transients in Electric Energy Systems and Devices. 3 cr. hrs.
Covers microsecond fast transients in power systems and devices resulting from lightning strokes, switching surges in power systems and devices, as well as impulse surges resulting from pulse width modulation in modern adjustable speed drives, using distributed parameter models and analysis of transmission lines and windings of transformers, generators and motors. Also covers successive reflections, transition points, waveform flattening techniques and surge arrester design applications for voltage buildup reduction and control are studied. Includes polyphase multi-velocity multiconductor system transients.

EECE 5290. Developments in Energy and Power. 1-3 cr. hrs.
Course content is announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Topics may include: electronics for machine and drive systems, electrical transients, faults and diagnostics and protection in power devices and systems, renewable energy systems, smart grids and advanced topics in the electric energy engineering area.
EECE 5310. Control Systems. 3 cr. hrs.
Review of continuous-time linear systems. Time-domain system analysis. Time-domain design of lead/lag and PID controllers. Root-Locus technique. Frequency-domain system analysis including Nyquist, Bode, and Nichols analysis and relative stability. Frequency-domain design/lead and PID controllers.

EECE 5320. Digital Control Systems. 3 cr. hrs.
Review of sampling processes, discrete time linear systems analysis and z-transform. Discrete time and sampled data state-variable analysis. Stability analysis, time domain and frequency-domain analysis and design. Analysis, design and computer implementation of digital algorithms and control systems.

EECE 5390. Developments in Control. 1-3 cr. hrs.
Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Possible topics include optimal, adaptive and robust control methods, digital control and nonlinear systems.

EECE 5410. Integrated Microelectronic Circuits. 3 cr. hrs.
Basic processing technology of integrated circuits, passive components and their parasitic effects, MOS transistors, bipolar transistors and diodes, design of silicon integrated circuits. Emphasizes the design of circuits to meet given requirements.

Fundamental physical principles of solid state devices are presented. The operation of modern semiconductor devices is explained from first principles and these principles are used to extend the students' knowledge of devices used in electronic circuits.

Sensor classification and transduction principles. Fundamental principles and theory of operation of various types of sensors, based on various technologies which include: optical, electrical, acoustical, thermal, magnetic, mechanical and chemical. Analysis of sensor signals. Study of sensor characteristics which include hysteresis, non-linearity, saturation, repeatability, sensitivity, selectivity and resolution. Design and practical implementations of various sensors for scientific, industrial and consumer applications.

EECE 5490. Developments in Devices. 1-3 cr. hrs.
Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Possible topics include: optoelectronic devices, nano-scale devices, solid-state devices, integrated electronic devices, power devices, electro-mechanical devices, quantum devices.

EECE 5510. Digital Signal Processing. 3 cr. hrs.
Introduction to the theory and practice of discrete-time signals and systems. Concepts covered include Fourier Transforms, Z-transforms, linear time invariant system analysis in the time and frequency domains, sampling theory and Discrete Fourier Transforms. Application of these concepts includes digital filter design techniques and the use of Fast Fourier Transforms for efficient frequency domain analysis. Labs and design projects related to specific signal processing applications are used to illustrate the material, including topics such as audio and image processing. Design Elective.

EECE 5520. Digital Image Processing. 3 cr. hrs.
Theory and practice of image digitization, processing, coding and analysis. Representations of images, image models. Techniques of image enhancement and restoration. Image compaction and coding. Segmentation and image understanding. Students have the opportunity to experiment with several image processing techniques using the MATLAB Image Processing Toolbox.

Course content is announced prior to each term. Students may enroll in the course more than once because subject matter changes. Depending upon the subject matter and the instructor, the class may be taught in traditional lecture format or as a seminar which focuses on readings from the current literature. Possible topics include filter design, DSP hardware, Nonlinear signal processing and multi-dimensional signal processing.

EECE 5560. Introduction to Communication Systems. 3 cr. hrs.
Survey of digital and analog communication systems including signal representation, modulation techniques, transmit and receive network design considerations.

EECE 5565. Optical Fiber Communications. 3 cr. hrs.
Fundamental principles and theories of optical fiber systems are introduced and developed. Review of electromagnetic principles of wave-guides. Step-Index and Graded-Index, single and multimode fibers. Signal analysis in optical fibers: mode interaction, attenuation, dispersion and pulse spreading. Operating characteristics of optical sources and photo-receivers with impact on system performance. Coupling to a fiber and distribution system. Optical fiber communication system design. Design Elective.

EECE 5570. Wireless Communications. 3 cr. hrs.
Fundamentals, analysis and design of cell systems, including trunking theory and grade of service. Large scale and small scale path loss analysis and modeling. Overview of modulation techniques, including amplitude and frequency modulating, and digital modulation techniques.

EECE 5590. Developments in Communications. 1-3 cr. hrs.
Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Possible topics include digital modulation and detection, coding theory, information theory.
EECE 5610. Object-Oriented Software Engineering. 3 cr. hrs.
 Presents advanced software engineering concepts in the context of object-oriented analysis and design. Topics include: concept of object-orientation, UML modeling techniques, use of CASE tools, use-case requirement analysis, modeling with classes, object-oriented design, design patterns, software quality, testing and correctness, software reuse and aspect-oriented software engineering. Prereq: COEN 2610 or equiv.

EECE 5620. Modern Programming Practices. 3 cr. hrs.
 Explores advanced topics in computer programming. Topics may include: design patterns, advanced graphical components, software component models such as Java Beans, the Java Security model, Java and databases, servlets, Java Server Pages, and Enterprise Java Beans.

EECE 5630. Software Testing. 3 cr. hrs.
 Examines the relationship of software testing to quality, emphasizing testing techniques and the role of testing in the validation of system requirements. Topics include: module and unit testing, integration, walkthroughs and inspections, verification and validation, preventing and detecting errors, selecting and implementing project metrics, and defining test plans and strategies traced from system requirements.

EECE 5650. Introduction to Algorithms. 3 cr. hrs.
 Introduction to the algorithms analysis. Topics to be covered include: the concepts of time and space complexity, advanced data structures, general issues in problem solving methodologies, greedy algorithms, dynamic programming, graph algorithms, AI-related algorithms, and an introduction to NP-completeness theory. Prereq: COSC 2010 or equiv.

EECE 5650. Introduction to Algorithms. 3 cr. hrs.
 Examines the relationship of software testing to quality, emphasizing testing techniques and the role of testing in the validation of system requirements. Topics include: module and unit testing, integration, walkthroughs and inspections, verification and validation, preventing and detecting errors, selecting and implementing project metrics, and defining test plans and strategies traced from system requirements.

EECE 5690. Developments in Computer Software. 3 cr. hrs.
 Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. Prereq: Cons. of instr.

EECE 5700. Computer Hardware. 3 cr. hrs.
 Overview of computer system design. Cost and performance specification. Design of arithmetic and logic units. Fundamentals of central processor architecture and a comparative study of computer instruction set architectures. Detailed study of microprocessors, including instruction execution timing and other timing considerations. Discussions of memory and I/O devices, including the interfaces to the CPU and I/O transfer techniques. Study of common bus standards.

EECE 5710. Computer Architecture. 3 cr. hrs.

EECE 5740. Advanced VHDL and FPGA Design. 3 cr. hrs.
 Presents the background, abstractions, and techniques for advanced digital circuits design and optimization. Emphasizes specification and synthesis using VHDL and prototyping using FPGAs of complex systems. Such systems represent examples from various application domains, including processors, image and video processing, filtering and other DSPs, and power electronics.

EECE 5790. Developments in Computer Hardware. 3 cr. hrs.
 Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. Prereq: Cons. of instr.
EECE 5870. Evolutionary Computation. 3 cr. hrs.
Covers a set of search methods based on the Darwinian principle of survival of the fittest. The methods include genetic algorithms, evolutionary strategies and evolutionary and genetic programming, which have been successfully applied to many different problem domains including optimization, learning, control, and scheduling. Provides students with the background and knowledge to implement various evolutionary computation algorithms, discusses trade-offs between different evolutionary algorithms and other search methods, and discusses issues related to the application and performance evaluation of evolutionary algorithms. Prereq: COSC 2010, MATH 1450, MATH 2105 or equiv.

EECE 5890. Developments in Computing. 1-3 cr. hrs.
Course content announced prior to each term. Students may enroll in the course more than once as subject matter changes. May be taught in traditional lecture format or as a seminar which focuses on readings from current literature. Possible topics include: advanced hardware (MPP, EPIC, VLIW), advanced software (enterprise systems, embedded software, real-time software) and advanced intelligent systems.

EECE 6010. Advanced Engineering Mathematics. 3 cr. hrs.
Linear algebra and matrix theory, ordinary differential equations and complex variables emphasizing both theoretical and numerical aspects as well as engineering applications. Prereq: MATH 2451 or equiv.

EECE 6020. Probability and Random Processes in Engineering. 3 cr. hrs.
Probability, random variables, statistics, and random processes, emphasizing both theoretical and numerical aspects as well as engineering applications. Prereq: MATH 2451 or equiv.

EECE 6090. Advanced Engineering 1. 3 cr. hrs.
Mathematics, image processing, signal processing, image reconstruction, and imaging systems in medical imaging applications. Offered fall term at the General Electric Medical Systems facility. This course extends beyond the Marquette term; students receive an IC grade initially. The IC will be changed to an A-F grade at the end of the course. Prereq: Cons. of instr.; GE employee.

EECE 6092. Advanced Engineering 2. 3 cr. hrs.
Problem solving methodology, software engineering tools and environment (typical topics: UNIX, C, data structures, object oriented paradigm, programming strategies), and hardware engineering tools (typical topics: analog and digital CAD, PALs, VME, applications). EECE 6092 and EECE 6810 may not both be used to meet degree requirements. Offered spring term at the General Electric Medical Systems facility. This course extends beyond the Marquette term; students receive an IC grade initially. The IC will be changed to an A-F grade at the end of the course. Prereq: Cons. of instr.; GE employee.

EECE 6094. Advanced Engineering 3. 3 cr. hrs.
Covers advanced concepts in medical imaging and systems. Offered spring term at the General Electric Medical Systems facility. This course extends beyond the Marquette term; students receive an IC grade initially. The IC will be changed to an A-F grade at the end of the course. Prereq: Cons. of instr.; GE employee.

EECE 6110. Advanced Electromagnetic Fields. 3 cr. hrs.
Solutions of Laplace and Poisson equations arising from electro and magneto static field configurations. Separation of variables, numerical relaxation, and conformal mapping techniques. Prereq: EECE 3110 or equiv.

EECE 6120. Electromagnetic Theory. 3 cr. hrs.
Review of Maxwell's equations and waves in dielectric and lossy media; image theory, induction theorem and Green's function. Plane, cylindrical and spherical wave functions; radiation and antennas; rectangular, cylindrical waveguides and cavities; spherical cavities. Perturbation and variation techniques and moment techniques. Prereq: EECE 3120 or equiv.

EECE 6130. Numerical Techniques in Electromagnetics. 3 cr. hrs.
Introduction and overview of numerical methods in electromagnetics, focusing on high frequency methods. Topics covered include: a review of analytic methods and the generalized multipole technique, finite difference methods, variational techniques, and the solution to integral equations via the method of moments. Prereq: ELEN 3120 and MATH 2451 or equiv.

EECE 6210. Advanced Electric Machines and Drives. 3 cr. hrs.
Machine characterization. Development and application of transformation theory to synchronous and induction machines to predict machine performance under steady state and abnormal conditions. Modeling of permanent magnet and switched reluctance machines, as well as other advanced machine systems. Dynamic performance prediction of electric machines and associated power electronics using equivalent network models and computer simulations. Prereq: ELEN 3210 and MATH 2451 or equiv.

Presents advanced concepts and methodologies in designing and modeling modern electric machines controlled and operated from electronically switched electric drives. Involves methods of analysis and computation of the adverse synergistic effects which occur between the space harmonics generated in electric machinery due to magnetic circuit topologies, time harmonics generated by electronic switching in the controllers/drives, and the impact of this synergism on losses, efficiency, torque quality and other performance issues. Includes full and rigorous analysis and inclusion of such space harmonics, and time harmonics. Studies, in detail, methods of mitigation or elimination of these effects using advance modeling concepts and tools. Prereq: ELEN 3210 or equiv.
EECE 6230. Finite Element Analysis. 3 cr. hrs.
Basic field formulations using Maxwell's electromagnetic field equations. General definitions and formulations of finite element discretization. Consideration of applications and method implementation. Application of the finite element method to engineering and design problems. Post processing, practical aspects and other considerations. Application of method involves the use of commercially available software packages as well as computer code developed during this course. Prereq: MATH 2451 or equiv.; and proficiency in computer programming.

EECE 6310. Modern Control Theory. 3 cr. hrs.
Review of linear algebra and matrices. State variable analysis of continuous-time and discrete-time systems. Controllability and observability of linear systems. Stability of linear and nonlinear systems. Design of feedback control systems. Introduction to optimal control theory. Prereq: EECE 6010 which may be taken concurrently; or MEEN 6101 which may be taken concurrently.

EECE 6320. Optimal Control. 3 cr. hrs.
Presents an in-depth understanding of the problems in optimal control theory and their applications. Presents calculus of variations, linear quadratic regulator design, dynamic programming, time-optimal, and output feedback regulating and tracking optimal control techniques for continuous-time systems. Presents discrete-time techniques for calculus of variations, linear quadratic tracking, output feedback optimal control, and time-optimal control. Also presents optimal observers. Prereq: EECE 6010 and EECE 6310 or equiv.

EECE 6330. Nonlinear and Adaptive Control. 3 cr. hrs.

EECE 6340. Stochastic Systems Estimation and Control. 3 cr. hrs.
Modeling probabilistic dynamical behavior with stochastic systems. Analysis of behavior of linear continuous and discrete time systems via simulation and analytical methods. Filter construction for state and parameter estimation using noisy and incomplete measurements for linear and nonlinear systems and measurements models. Design of optimal controllers based on quadratic criteria for linear stochastic systems.

EECE 6420. Infrared and Photonics Sensors: Theory and Applications. 3 cr. hrs.

EECE 6430. Microelectromechanical Systems and Sensors. 3 cr. hrs.
Overview of microelectromechanical-MEMS-transducers and sensors. Basic engineering sciences and fundamental principles relevant to mechanical sensors and micromachined mechanical transducers. Mathematical models and design of microelectromechanical systems. Microfabrication techniques, materials and processes. Mechanical transduction techniques, pressure sensors, force and torque sensors, inertial sensors, flow sensors, micromachined resonant sensors, micromachined chemical sensors. Prereq: ELEN 3110 or equiv.

EECE 6440. Surface-Acoustic-Wave Devices. 3 cr. hrs.
Theory of surface and other acoustic modes; design, analysis, and performance of interdigital devices; multistrip couplers; SAW resonators; dispersive delay lines; system applications; current research areas. Prereq: ELEN 3020 and ELEN 3110 or equiv.

EECE 6510. Optimal and Adaptive Digital Signal Processing. 3 cr. hrs.
Introduction to optimal and adaptive signal processing theory and applications. Topics include: statistically optimal gradient descent methods, such as least-mean-squares and minimal error methods, least squares and recursive least squares, Wiener filters, linear prediction, Kalman filters and performance and convergence analysis techniques. Prereq: EECE 5510 and EECE 6020 or equiv.

EECE 6520. Digital Processing of Speech Signals. 3 cr. hrs.
Introduction to the fundamentals of speech processing, including speech production and perception models and frequency-domain analysis methods such as, linear predictive coding and cepstral analysis. Applications studied include: speech coding, enhancement, recognition and synthesis. Prereq: EECE 5510 or equiv.

EECE 6530. Chaos and Nonlinear Signal Processing. 3 cr. hrs.
Introduces the theory and practice for analyzing chaotic and nonlinear signals. Examines methods for finding hidden structures in signals and time series, using techniques such as phase space reconstruction. Discusses topics previously mentioned along with machine learning, time series analysis, adaptive signal processing, wavelets and nonlinear dynamics. Prereq: EECE 5510 or equiv.

EECE 6560. Information and Coding Theory. 3 cr. hrs.
Introduction to information measure, mutual information, self-information, entropy, encoding of information, discrete and continuous channels, channel capacity, error detection, error correcting codes, group codes, cyclic codes, BCH codes, convolution codes, and advanced codes.
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EECE 6710. Computer Architecture. 3 cr. hrs.

EECE 6810. Algorithm Analysis and Applications. 3 cr. hrs.
Introduction to the analysis of algorithms. Topics include: asymptotic complexity notation, recursion analysis, basic and advanced data structures, sorting methodologies, dynamic programming, and graph algorithms, including heuristic search techniques such as best-first and A-star algorithms. Advanced topics include NP-completeness theory and linear programming. Prereq: EECE 2710 and MATH 1451 or equiv.

EECE 6820. Artificial Intelligence. 3 cr. hrs.
Provides a comprehensive survey of artificial intelligence. Topics include: search, logic, planning, uncertainty, learning, communication and perception, robotics and philosophical foundations of artificial intelligence. Prereq: COSC 2010, MATH 1450, MATH 2105 or equiv.

EECE 6822. Machine Learning. 3 cr. hrs.
An introduction to a range of adaptive computer algorithms that learn models from data. Explores the theoretical foundations of machine learning, including computational learning theory and PAC learnability. Examples of machine learning algorithms studied include: decision trees, artificial neural networks, Bayesian learners, evolutionary algorithms and ensemble techniques. Prereq: EECE 6820 or equiv.

EECE 6830. Pattern Recognition. 3 cr. hrs.
Theory and application of statistical pattern recognition, hypothesis testing and parameter estimation. Topics include: probability distribution models, Bayesian decision theory and hypothesis testing, classical and modern approaches to parameter estimation, parametric and non-parametric classifiers. Also, covered are feature selection and transformation techniques such as Principal Components Analysis, a wide range of classifier models and supervised and unsupervised clustering. Prereq: EECE 6020 or equiv.

EECE 6840. Neural Networks and Neural Computing. 3 cr. hrs.

EECE 6931. Topics in Electrical and Computer Engineering. 1-5 cr. hrs.
Course content announced prior to each offering. Students may enroll more than once as subject matter changes. Possible topics include computer operating systems, multiprogramming and multi-processing systems, computer architecture, optimal and adaptive control, stochastic control, estimation theory, and nonlinear analysis.

EECE 6932. Advanced Topics in Electrical and Computer Engineering. 3 cr. hrs.
Course content announced prior to each offering. Students may enroll more than once as subject matter changes. Possible topics include: computer operating systems, multiprogramming and multi-processing systems, computer architecture, optimal and adaptive control, stochastic control, estimation theory, and nonlinear analysis.

EECE 6952. Artificial Intelligence. 3 cr. hrs.
Provides a comprehensive survey of artificial intelligence. Topics include: search, logic, planning, uncertainty, learning, communication and perception, robotics and philosophical foundations of artificial intelligence. Prereq: COSC 2010, MATH 1450, MATH 2105 or equiv.

EECE 6953. Seminar in Electrical and Computer Engineering. 0-3 cr. hrs.
0 credit will be SNC/UNC grade assessment; 1-3 credits will be graded. Prereq: Cons. of instr.

EECE 6964. Practicum for Research and Development in Computing. 3 cr. hrs.
Provides students, who are enrolled in the M.S. in computing program, an opportunity to participate in the practice of research and/or development in the area of computing. Course Guidelines are available from EECE and MICS Departments. Available only to full-time students. At most, six credits of EECE 6964 OR MICS 6964 may be counted toward graduation. S/U grade assessment. Prereq: 3.00 MU GPA; must be enrolled in Plan B option of the M.S. in computing program and have completed at least 21 credit hours of course work, with 15 credit hours earned in graduate (6000-level) courses.

EECE 6995. Independent Study in Electrical and Computer Engineering. 1-5 cr. hrs.
Graduate independent study project of either a theoretical or experimental nature. Prereq: Cons. of instr. and cons. of dept. ch.

EECE 6999. Master's Thesis. 1-6 cr. hrs.
S/U grade assessment. Prereq: Cons. of instr.

EECE 8932. Advanced Topics in Electrical and Computer Engineering. 3 cr. hrs.
Course content announced prior to each offering. Students may enroll more than once as subject matter changes. Possible topics include: computer operating systems, multiprogramming and multi-processing systems, computer architecture, optimal and adaptive control, stochastic control, estimation theory, and nonlinear analysis. Prereq: Cons. of instr.

EECE 8995. Independent Study in Electrical and Computer Engineering. 1-5 cr. hrs.
Graduate independent study project of either a theoretical or experimental nature. Prereq: Cons. of instr. and cons. of dept. ch.

EECE 8999. Doctoral Dissertation. 1-12 cr. hrs.
S/U grade assessment. Prereq: Cons. of instr.
EECE 9970. Graduate Standing Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9974. Graduate Fellowship: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9975. Graduate Assistant Teaching: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9976. Graduate Assistant Research: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9986. Master's Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9987. Doctoral Comprehensive Exam Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9988. Doctoral Comprehensive Exam Preparation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9989. Doctoral Comprehensive Exam Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9994. Master's Thesis Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9995. Master's Thesis Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9996. Master's Thesis Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9997. Doctoral Dissertation Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9998. Doctoral Dissertation Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

EECE 9999. Doctoral Dissertation Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.