Department of Electrical and Computer Engineering

Chairperson: Majeed Hayat, Ph.D.
Department of Electrical and Computer Engineering website (http://www.marquette.edu/engineering/electrical_computer)

The Department of Electrical and Computer Engineering offers curricula that lead to a bachelor of science degree in electrical engineering or a bachelor of science degree in computer engineering.

Mission

The Department of Electrical and Computer Engineering embraces the missions of Marquette University and its Opus 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; by research that advances the frontiers of technical and scientific knowledge and by service to professional and civic communities.

Engineering is the professional art of applying science and mathematics to the efficient conversion of natural resources and to the manipulation of information for human benefit. The basic concepts in this definition can be expanded, particularly for the electrical or computer engineer, by considering his or her activities. These usually involve 1) the processing and control of energy, 2) the processing and control of information, 3) the processing and control of materials. Certainly any educational experience in electrical engineering or computer engineering should be evaluated for the student in terms of its contribution in one or more of these areas.

However, this is not the only consideration. Equally important is the concept of engineering as a dynamic profession. In terms of the educational process, this means that attention must be directed to preparing the student for types of processing and control, which have not yet been developed or perhaps even discovered. The young engineer must be prepared to cope with devices and systems which will appear years into the future, from the viewpoint of the scientific principles on which the design of these future devices and systems will be based.

There is another important consideration in the practice of electrical and computer engineering. An engineer is called on for many and varied activities but as diversified as these may be, when carefully examined, they lead to this conclusion: Problem-solving is the engineer’s most important activity. From the educator’s viewpoint, this naturally should lead to a planned, conscious effort to develop the young engineer’s problem-solving ability to the limits of his or her God-given talents. In this regard, it is important to note that since engineers’ problems are sometimes creative, sometimes analytic, and sometimes experimental, their educational experience must give practice in each of these areas and in all types of problems. Significant design experience is an essential part of the engineer’s education.

Finally, the engineer is an individual, a citizen who needs to develop a sense of moral and ethical values on a plane consistent with his or her education in other areas. In the educational process, this requires that a good balance be developed between the technical and social-humanistic content.

The electrical engineering and computer engineering curricula at Marquette University are carefully designed to meet the requirements of each student. Opportunities are provided for each student to develop in the direction of personal interests and at a rate corresponding to individual ability. Coherent elective programs are planned with each student consistent with his or her ability and professional goals. Moreover, superior students have the opportunity for independent study and for participation in research activity.

Educational Objectives

The Educational Objectives for the Electrical Engineering and Computer Engineering Programs derive from the department’s vision for our graduates. Alumni of these programs, particularly those individuals who have completed their undergraduate education within the last two to five years, will be thriving professionals who apply the knowledge, skills, and values gained through their study of Computer or Electrical Engineering at Marquette University.

Specifically, our graduates are:

1. Engaged in solving significant problems in engineering or another field, as employees in the public or private sector, or as students pursuing an advanced or professional degree, or as volunteers.
2. Capably contributing as members of engineering or other problem-solving teams and communicating effectively both within the team and to the team’s clients.
3. Advancing in their professional careers — taking on increasing responsibilities as well as leadership roles.
4. Continually learning, whether in a formal degree program or by participating in professional conferences and continuing education programs.
5. Acting responsibly when making professional and personal decisions — serving as examples to those around them.
Computer Science Minor

Students in Electrical or Computer Engineering may obtain a minor in computer science by following the guidelines listed in the Concentrations and Minors (http://bulletin.marquette.edu/undergrad/collegeofengineering/nonengineeringminors) section of the Opus College of Engineering bulletin.

Non-Electrical/Computer Engineering Minors

Students in the electrical engineering curriculum who are interested in obtaining a minor (or major) in any other area should consult with their advisers during their freshman or sophomore year in order to plan their schedules to meet their particular objectives with a minimum amount of overload credits. Students wishing to achieve a non-engineering minor should follow the guidelines listed in the Concentrations and Minors (http://bulletin.marquette.edu/undergrad/collegeofengineering/nonengineeringminors) section of the Opus College of Engineering bulletin.

Five Year B.S./M.S. Program

This program allows students to receive a bachelor of science degree in either electrical engineering or computer engineering, depending on the student’s undergraduate major, and a master of science degree in electrical engineering in five years. Students with qualifying grade point averages enroll in the program during their junior year. Additional information about this program is available in the most recent Marquette University Graduate bulletin.

Electrical Engineering

The electrical engineering major provides students with a comprehensive electrical engineering background including course specialties in five broad categories: Electronic Devices and Systems; Signals, Systems & Control; Electromagnetic Fields and Communication; Power and Energy Systems and Computer Hardware and Software.

### Freshman

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<th>First Term</th>
<th>Hours</th>
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### Sophomore

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<td>ELEN 2020</td>
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<td>CHEM 1001</td>
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<td>4</td>
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### Junior

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<td>ELEN 3110</td>
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</table>
The four courses in the Discovery Tier (DSCV) of the MCC must be completed in the same theme and include the following content areas: Humanities (HUM), Social Science (SSC), Natural Science and Mathematics (NSM) and one elective (ELE), which is an additional course from any of the three content areas. A maximum of two courses in the Discovery Tier can apply towards a primary major. Students must also complete the Writing Intensive (WRIT) and Engaging Social System and Values 2 (ESSV2) requirements of the MCC. These requirements can be fulfilled through designated courses in the Discovery Tier or other degree requirements.

The six EE Electives must satisfy both a breadth and a depth requirement. To satisfy the breadth requirement, the student must take EE electives in at least three of the following five areas: Electronic Devices and Systems; Signals, Systems and Control; Electromagnetic Fields and Communication; Power and Energy Systems; and Computer Hardware and Software. To satisfy the depth requirement, the student must take at least three EE electives in one of the aforementioned areas. A course listed in two concentration areas may be counted toward only one elective.

The science/math elective can be fulfilled with any upper division math or physics course (except PHYS 4031 Electricity and Magnetism 1) or any biology or chemistry course for which the prerequisite requirements are met.

Areas of Concentration within Electrical Engineering

The Electrical Engineering curriculum has six electives designated as EE electives. At least five of these electives must be courses with an ELEN, EECE or COEN number as listed for the concentration areas. The remaining two electives can be in any technical area. The student, in consultation with his or her adviser, must design the elective program to meet both a breadth requirement and a depth requirement. To meet the breadth requirement, students must choose at least one course from each of at least three of the concentration areas. To meet the depth requirement, at least three courses must be chosen from within a single concentration area. These areas of concentration and the courses in each area are described below.

Electronic Devices and Systems

Device Systems is based on the fundamental principles of solid state devices. These fundamentals are applied to the design and application of integrated circuits, nanotechnology, and state of the art devices. The following ELEN and EECE courses are available in the Device Systems area:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>EECE 4410</td>
<td>Integrated Microelectronic Circuits</td>
<td>3</td>
</tr>
<tr>
<td>EECE 4740</td>
<td>Advanced VHDL and FPGA Design</td>
<td>3</td>
</tr>
<tr>
<td>ELEN 4430</td>
<td>Physical Principles of Solid State Devices</td>
<td>3</td>
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<tr>
<td>ELEN 4450</td>
<td>Surface Acoustic Wave Devices</td>
<td>3</td>
</tr>
<tr>
<td>ELEN 4460</td>
<td>Sensor Devices: Theory, Design, and Applications</td>
<td>3</td>
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<tr>
<td>ELEN 4490</td>
<td>Developments in Devices</td>
<td>1-3</td>
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<tr>
<td>ELEN 4565</td>
<td>Optical Fiber Communications</td>
<td>3</td>
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</table>

Signals, Systems and Controls

Control system engineering develops a general background in automatic controls and systems engineering with a fundamental emphasis on linear feedback systems and applications of computers. Course work in advanced controls, digital systems, and large-scale design is included. The following ELEN and EECE elective courses are available in the Systems and Control area:
Electromagnetic Fields and Communication

Applied electromagnetics and waves involve high frequency waves as applied to communications and sensing applications. Principles and applications of wireless communications are included. Fiber optics, antennas, modern communication cell systems, analog and digital modulation techniques, and sensor principles and applications are investigated. The following ELEN and EECE elective courses are available in the Electromagnetic Fields and Communication area:

ELEN 3120  Electromagnetic Fields 2  3
ELEN 4130  Antenna Theory and Design  3
ELEN 4150  Applied Finite Elements in Electromagnetics  3
EECE 4510  Digital Signal Processing  3
ELEN 4560  Introduction to Communication Systems  3
ELEN 4565  Optical Fiber Communications  3
ELEN 4570  Wireless Communications  3
ELEN 4190  Developments in Electromagnetics  1-3
ELEN 4590  Developments in Communications  1-3
ELEN 4110  Microwave Engineering  3

Power and Energy Systems

Power engineering emphasizes the control and conversion of electrical energy. Motors and generators with their associated electronic power controls, power distribution systems and control systems are examined. Modern computer-aided analysis is brought to bear on the design and analysis of power devices and power systems. The following ELEN elective courses are available in the Power and Energy area:

ELEN 3210  Electric Drives  3
ELEN 4210  Design and Analysis of Electric Motor-Drive Systems  3
ELEN 4220  Power Electronics for Renewable Energy Systems  3
ELEN 4230  Renewable and Legacy Electric Energy Systems Analysis  3
ELEN 4240  Protection and Monitoring of Electric Energy Systems  3
ELEN 4250  Transients in Electric Energy Systems and Devices  3
ELEN 4290  Developments in Energy and Power  1-3

Computer Hardware and Software

The computer hardware and software concentration provides courses that give a greater exposure to and more in-depth study of computer principles and applications. The emphasis in these courses is on small computers, particularly microcomputer concepts and applications. The following COEN and EECE courses are available in the Computer Hardware and Software area:

COEN 4620  Modern Programming Practices  3
COEN 4630  Software Testing  3
COEN 4710  Computer Hardware  3
COEN 4720  Embedded Systems Design  3
COEN 4730  Computer Architecture  3
COEN 4810  Database Applications  3
COEN 4820  Operating Systems and Networking  3
COEN 4830  Introduction to Computer Graphics  3
COEN 4840  Computer Security  3
COEN 4850  Introduction to Intelligent Systems  3
COEN 4860  Introduction to Neural Networks and Fuzzy Systems  3
Preparing for Graduate Study

The ELEN curriculum provides an excellent foundation for students wishing to pursue graduate studies in most electrical engineering graduate programs.

Computer Engineering Major

In addition to the electrical engineering major outlined above, the Department of Electrical and Computer Engineering offers a curriculum leading to a bachelor of science degree in computer engineering. The computer engineering curriculum provides a solid foundation in electrical engineering fundamentals, as well as a comprehensive study of computer software and hardware systems. Through an ample elective program, students can customize their studies to their individual interests, emphasizing hardware engineering, software engineering, or intelligent systems.

<table>
<thead>
<tr>
<th>Freshman</th>
<th>First Term</th>
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#### Senior

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Total credit hours: 134

\(^1\) The four courses in the Discovery Tier (DSCV) of the MCC must be completed in the same theme and include the following content areas: Humanities (HUM), Social Science (SSC), Natural Science and Mathematics (NSM) and one elective (ELE), which is an additional course from any of the three content areas. A maximum of two courses in the Discovery Tier can apply towards a primary major.

\(^2\) Students must also complete the Writing Intensive (WRIT) and Engaging Social System and Values 2 (ESSV2) requirements of the MCC. These requirements can be fulfilled through designated courses in the Discovery Tier or other degree requirements.

\(^3\) At least five of the six electives must be from the COEN areas of concentration. The remaining elective can be in any technical area. Of the five electives, one must be in the Hardware Engineering area, one must be in the Software Engineering area, and one must be in the Intelligent Systems area. Of the five electives, three must be in one of the following areas: Hardware Engineering, Software Engineering, or Intelligent Systems. A course listed in two concentration areas may be counted toward only one elective requirement.

### Areas of Concentration within Computer Engineering

The Computer Engineering curriculum has six electives designated as COEN/TECH electives. At least five of these electives must be courses from the COEN areas of concentration. The remaining elective can be in any technical area. The student, in consultation with his or her adviser, must design the elective program to meet both a breadth requirement and a depth requirement. To meet the breadth requirement, one COEN elective must be in the Hardware area, a second COEN elective must be in the Software area and a third COEN elective must be in the Intelligent Systems area. To meet the depth requirement, a total of three electives must be in one of the following three areas: Hardware, Software and Intelligent Systems. These areas of concentration and the courses in each area are described below.

#### Hardware

Hardware includes the study of computer architectures, computer chip technology, peripheral devices, signal processing, interface design and the like. The following COEN elective courses are available in the Hardware area:

<table>
<thead>
<tr>
<th>Breadth or Depth</th>
<th>COEN elective courses</th>
<th>Hours</th>
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<tbody>
<tr>
<td></td>
<td>COEN 4730 Computer Architecture</td>
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<td></td>
<td>EECE 4740 Advanced VHDL and FPGA Design</td>
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<td>COEN 4790 Developments in Computer Hardware</td>
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<td></td>
<td>EECE 4410 Integrated Microelectronic Circuits</td>
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</table>

**Depth Only**

|                  | ELEN 3030 Analog Electronics | 3     |
|                  | ELEN 3025 Electrical Instrumentation Laboratory & ELEN 3035 and Analog Electronics Laboratory | 4     |
|                  | EECE 4510 Digital Signal Processing | 3     |
|                  | ELEN 4310 Control Systems | 3     |
|                  | ELEN 4560 Introduction to Communication Systems | 3     |
|                  | COSC 4290 Real-Time and Embedded Systems | 3     |

#### Software

Software emphasizes the design of software systems and includes concerns such as the user interface, expansibility and maintainability, efficiency in time and computing resources, software testing, security, etc. The following COEN elective courses are available in the Software area:

<table>
<thead>
<tr>
<th>Breadth or Depth</th>
<th>COEN elective courses</th>
<th>Hours</th>
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<tr>
<td></td>
<td>COEN 4610 Object-Oriented Software Engineering</td>
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<tr>
<td></td>
<td>COEN 4620 Modern Programming Practices</td>
<td>3</td>
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</tbody>
</table>
COEN 4630  Software Testing  3
COEN 4650  Introduction to Algorithms  3
COEN 4690  Developments in Computer Software  3
Depth Only
COEN 4810  Database Applications  3
  or COSC 4800  Principles of Database Systems  3
COEN 4830  Introduction to Computer Graphics  3
COEN 4840  Computer Security  3
COSC 3410  Programming Languages  3
COSC 4400  Compiler Construction  3
COSC 4860  Component-Based Software Construction  3
COSC 4300  Networks and Internets  3
COSC 3550  Programming Computer Games  3

Intelligent Systems
Intelligent Systems includes the study of artificial intelligence, neural networks, evolutionary computing, design of algorithms, and computer security models. Students wishing to concentrate in this area are encouraged to take ELEN 3020 as one of their non-COEN electives. The following COEN elective courses are available in the Intelligent Systems area:

Breadth or Depth
COEN 4650  Introduction to Algorithms  3
COEN 4850  Introduction to Intelligent Systems  3
  or COSC 4600  Fundamentals of Artificial Intelligence  3
COEN 4860  Introduction to Neural Networks and Fuzzy Systems  3
COEN 4870  Evolutionary Computation  3
Depth Only
COEN 4840  Computer Security  3
COSC 4110  Formal Languages and Computability  3
COSC 4610  Data Mining  3
COSC 3550  Programming Computer Games  3

Preparing for Graduate Study
The COEN curriculum provides an excellent foundation for students wishing to pursue graduate studies in most computer engineering, computer science, and electrical engineering graduate programs. However, students who wish to enter the Marquette University graduate program in Electrical Engineering must take ELEN 3020 Linear Systems Analysis as their non-COEN elective in order to meet the entrance requirements.

Electrical Engineering Minor
The Department of Electrical and Computer Engineering offers a minor in electrical engineering to undergraduate students in the university except those students in electrical engineering. Completion of the minor will be noted on the student’s transcript if the following requirements are met. A minimum of twenty-five hours including:

EECE 2010  Electric Circuits 1  3
EECE 2015  Circuits Laboratory 1  1
ELEN 2020  Electric Circuits 2  3
  or COEN 2020  Electric Circuits 2  3
EECE 2030  Digital Electronics  3
EECE 2035  Circuits Laboratory 2  1
EECE 3010  Electronic Devices and Applications  3
EECE 3015  Digital Electronics Laboratory  2
ELEN 3020  Linear Systems Analysis  3
  or BIEN 3300  Signals and Systems for Biomedical Engineering  3
ELEN 3110  Electromagnetic Fields 1  3
At least half of these credit hours must be taken at Marquette University and a grade of C or better must be earned in each course for the minor.

Computer Engineering Minor

The Department of Electrical and Computer Engineering offers a minor in computer engineering to undergraduate students in the university except those students in computer engineering. Completion of the minor will be noted on the student’s transcript if the following requirements are met. A minimum of twenty-four hours including:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<td>EECE 2010</td>
<td>Electric Circuits 1</td>
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<tr>
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<td>COEN 2610</td>
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Total Credit Hours 24

At least half of these credit hours must be taken at Marquette University and a grade of C or better must be earned in each course for the minor.

Computer Engineering Courses

COEN 2020. Electric Circuits 2. 3 cr. hrs.

COEN 2610. Software Methodologies. 3 cr. hrs.
The first course in software engineering, covering the software life cycle, proper selection of data structures and algorithms, and the availability and choice of programming paradigms for appropriate design and implementation of well-engineered software. An open laboratory and significant programming experiences form an integral part of this course. Prereq: EECE 1610 or COSC 1010.

COEN 4610. 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.

COEN 4620. 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. Prereq: COSC 2100 or COSC 2010.

COEN 4630. 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. Prereq: EECE 2710, COSC 2100, COSC 2010, or equivalent experience.

COEN 4650. 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.

COEN 4690. Developments in Computer Software. 3 cr. hrs.
Course content is announced prior to each semester. Students may enroll in the course more than once because subject matter changes. COEN design elective. Prereq: Cons. of instr.
COEN 4710. 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. Prereq: EEEC 2710 and EEEC 2030; or COSC 2200 and EEEC 2030.

COEN 4720. Embedded Systems Design. 3 cr. hrs.
This course introduces students to embedded systems, the types of hardware that can support such systems, and the interfacing used in embedded systems. The course is a combined laboratory and lecture course, which directly applies the embedded systems techniques using hardware description and assembly languages to field programmable gate array technology. Prereq: COEN 4710 and EEEC 3015.

COEN 4730. Computer Architecture. 3 cr. hrs.

COEN 4790. Developments in Computer Hardware. 3 cr. hrs.
Course content is announced prior to each semester. Students may enroll in the course more than once because subject matter changes. COEN design elective. Prereq: Cons. of instr.

COEN 4810. Database Applications. 3 cr. hrs.
Presents the design and application of databases. Topics include: models for databases, database query languages, database design methods, methods for storing and retrieving information from a database, database optimizations, transaction processing, and a brief examination of some advanced concepts, including object databases, distributed databases and database security. Prereq: COSC 2100 or COSC 2100 or equiv.

COEN 4820. Operating Systems and Networking. 3 cr. hrs.
Introduces the fundamental concepts of operating systems together with the basics of networking and communications including: memory management, scheduling, concurrent processing, device management, file systems, networking, security, and system performance. Examples are drawn from legacy and modern operating systems. Prereq: COSC 2100 or COSC 2100.

COEN 4830. Introduction to Computer Graphics. 3 cr. hrs.
Introduction to computer graphics algorithm design and implementation; includes considerable actual computer graphics experience. Topics include: point-plotting and line-drawing techniques, two-dimensional curve fitting, two- and three-dimensional graphics, clipping, windowing, hidden line removal, modeling, input/output devices, and other topics as future trends dictate. Prereq: Proficiency in at least one high level computing language.

COEN 4840. Computer Security. 3 cr. hrs.
Introduction to the important issues in computer security, including cryptography, program security, operating system security, database security, and network security. Also discusses the legal, ethical and privacy issues that arise in computer security. Programming projects enable the student to practice implementing many of the security measures discussed in class. Prereq: COSC 2100 or COSC 2100 or equiv.

COEN 4850. Introduction to Intelligent Systems. 3 cr. hrs.
Provides a broad exposure to intelligent systems, including related fields such as artificial and computational intelligence. Topics include: intelligent agents, search, game playing, propositional logic and first-order predicate calculus, uncertainty, learning, communication and perception, and philosophical foundations of intelligent systems. Prereq: COSC 2100, MATH 1450 and MATH 2105.

COEN 4860. Introduction to Neural Networks and Fuzzy Systems. 3 cr. hrs.
Concepts of artificial neural network architectures and training algorithms, supervised and unsupervised learning, linear and non-linear neural networks, feedback neural networks, applications in scientific and engineering areas, fundamentals of fuzzy sets and fuzzy logic, fuzzy rules and inference systems, fuzzy pattern classification and clustering analysis and fuzzy control systems. Prereq: COSC 2100 and MATH 1451.

COEN 4870. 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 2100, MATH 1450 and MATH 2105.

COEN 4890. Developments in Computer Applications. 1-3 cr. hrs.
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 advanced hardware (MPP, EPIC, VLIW), advanced software (enterprise systems, embedded software, real-time software) and advanced intelligent systems. Prereq: Cons. of instr. or Sr. stndg.

COEN 4920. Principles of Design. 3 cr. hrs.
Course content focuses on a structured product design and development process that includes project definition, customer needs identification, product specification, concept generation, and concept selection. Course also focuses on issues related to teamwork, project management, and effective communication. Student team design projects culminate in the development of a technically and economically viable concept and a proposal for future development of this concept (done in the second semester of this two-course sequence). 2 hr. lec., 1 hr. disc. Prereq: Sr. stndg.; Co-op students, Jr. stndg. Cross-listed with BIEN 4920, ELEN 4920 and MEEN 4920.
Electrical Computer Engineer Courses

EECE 1610. Introduction to Computer Programming. 3 cr. hrs.
Students are introduced to computer programming with an emphasis on object-oriented programming (OOP) and OOP design methodologies. The students learn about typical programming constructs including data types, data structures, control structures, data input and output techniques as well as several algorithms used for solving engineering problems. In addition, students learn to use modern programming tools in an integrated development environment by focusing on developing software solutions to significant engineering problems. Prereq: Enrolled in the OPUS College of Engineering.

EECE 1953. Freshman Seminar 1. 1 cr. hr.
Introduction to electrical engineering and computer engineering through presentations by faculty, graduate students, upper-class undergraduate students, alumni and industry representatives. A formal opportunity for first-year COEN and ELEN students to interact with their peers and other members of the EECE Department. Prereq: Enrolled in the OPUS College of Engineering.

EECE 1954. Freshman Seminar 2. 1 cr. hr.
Continuation of EECE 1953. COEN and ELEN students have further opportunities to investigate electrical engineering and computer engineering applications through presentations by faculty, graduate students, upper-class undergraduate students, alumni and industry representatives. Prereq: Enrolled in the OPUS College of Engineering.

EECE 2010. Electric Circuits 1. 3 cr. hrs.

EECE 2015. Circuits Laboratory 1. 1 cr. hr.
Introduction to circuit design, construction, and test. The basics of circuit construction techniques and electronic test measurement skills are covered. Circuit components such as resistors, inductors, capacitors and op-amps are used. Emphasis placed on DC and transient response of circuits. 1 hr. lec., 2 hrs. lab. EECE 2010 must be taken concurrently.

EECE 2030. Digital Electronics. 3 cr. hrs.
Introduces students to the basic principles of digital circuit analysis and design. Topics covered include: Boolean Algebra, number systems, basic logic gates, standard combinational circuits, combinational design, timing diagrams, flip-flops, sequential design, standard sequential circuits and programmable logic devices. Prereq: Soph. standing.

EECE 2035. Circuits Laboratory 2. 1 cr. hr.
Circuit design, construction and test skills are expanded to include digital circuits and programmable logic devices as well as passive and active filters. Emphasis placed on DC, AC and transient response of circuits containing passive and active devices. 1 hr. lec., 2 hrs. lab. Prereq: EECE 2010, EECE 2015, ELEN 2020 or COEN 2020, either of which may be taken concurrently and EECE 2030, which may be taken concurrently.

EECE 2710. Introduction to Computer Hardware and Software. 3 cr. hrs.
Overview of computer hardware: information representation, the control unit, implementation of instruction sets, memories and storage devices, internal bus organization, the arithmetic/logic unit, the input/output unit, interfacing peripherals. Overview of computer software, operating system components: memory management, input/output, file management, scheduling, resource management. Layered operating system design, programming languages and language translators, application layer design, software tools, and system design and design process. Programming exercises in machine and assembly language and in the JAVA programming language. Prereq: EECE 1610 or COSC 1010.

EECE 3010. Electronic Devices and Applications. 3 cr. hrs.
Electronic components are discussed including semiconducting diodes, bipolar junction transistors, field effect transistors, etc. These devices are analyzed from their terminal characteristics and their behavior in representative electronic circuits. Applications for devices include simple power supply analysis and design, class A amplifier analysis including transistor biasing and stability analysis, simple digital logic gates, etc. Prereq: EECE 2010.

EECE 3015. Digital Electronics Laboratory. 2 cr. hrs.
Gaining experience in the design, assembly, testing and trouble-shooting of digital electronic circuits. Experiments encompass a wide range of topics, such as: basic logic gates, integrated circuit specifications, Boolean algebra implementations, standard combinational circuits, sequential circuit design, standard sequential circuits, programmable logic devices, digital interfacing and microprocessors. 7400 series ICS, PALs, PROMs, and microprocessor devices are used. 1 hr. lec., 3 hrs. lab. Prereq: EECE 2030 and EECE 2710, which may be taken concurrently; or EECE 2030 and BIEN 3200, which may be taken concurrently.
EECE 4410. 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. Emphasis is placed on the design of circuits to meet given requirements. Design Elective. Prereq: EECE 3010 and ELEN 2020.

EECE 4510. 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. Prereq: ELEN 3020 (or BIEN 3300) or consent of instructor.

EECE 4740. Advanced VHDL and FPGA Design. 3 cr. hrs.
Present the background, abstractions, and techniques for advanced digital circuits design and optimization. Emphasis is placed on specification and synthesis using VHDL and on 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. Prereq: EECE 2030, EECE 3015.

Electrical Engineering Courses

ELEN 2020. Electric Circuits 2. 3 cr. hrs.

ELEN 2040. Engineering Systems. 3 cr. hrs.
Focuses on the modeling and solution of physical systems including translational and rotational mechanical systems, mass balance systems (fluids, chemical), thermal systems and electrical systems. Analytic solution techniques stress the universality of the mathematics for all systems. Computer solutions using MatLab and Simulink are used to further investigate the linear system behavior and to introduce non-linear system behavior. Prereq: ELEN 2010 and either MATH 2450 or MATH 1455.

ELEN 3001. Electric Circuits and Machinery. 3 cr. hrs.
Circuit modeling; basic solution methods for d-c and a-c circuits; d-c and a-c machines. May not be taken for credit by EECE students.

ELEN 3020. Linear Systems Analysis. 3 cr. hrs.
Mathematical models of continuous-time and discrete-time signals and systems are studied. The time domain viewpoint is developed for linear time invariant systems using the impulse response and convolution integral. The frequency domain viewpoint is also explored through the Fourier Series and Fourier Transform. Basic filtering concepts including simple design problems are covered. Application of the Laplace transform to block diagrams, linear feedback, and stability including Bode plots are discussed. The sampling theorem, the z-transform, and the Discrete Fourier Transform are introduced. Examples of electrical, mechanical and biomedical signals and systems are used extensively throughout the course. Prereq: ELEN 2020 and MATH 2451; or BIEN 2300 and MATH 2451; or ELEN 3001 and MATH 2451.

ELEN 3025. Electrical Instrumentation Laboratory. 2 cr. hrs.
Develops familiarity with typical electronic instruments and terminology. Combines theory with experience to analyze and design electrical networks. Learn experimental technique and documentation. 1 hr. lec., 3 hrs. lab. Prereq: EECE 3010, ELEN 2020 and EECE 2015.

ELEN 3030. Analog Electronics. 3 cr. hrs.
Analysis and design of analog electronic circuits. Low and high frequency models for both bipolar and field effect transistors. Design features and operating characteristics of integrated linear circuits with emphasis on operational amplifiers and op-amp circuits. Prereq: EECE 3010 and ELEN 2020.

ELEN 3035. Analog Electronics Laboratory. 2 cr. hrs.
Gain experience in the design, assembly, testing and trouble-shooting of analog electronic circuits. Experiments encompass a wide range of topics, such as: amplifiers, filters, power supplies, power control, oscillators and communication circuits. Transistors, op-amps, general purpose and specific purpose devices are used. 1 hr. lec., 3 hrs. lab. Prereq: ELEN 3030 and ELEN 3025.

ELEN 3110. Electromagnetic Fields 1. 3 cr. hrs.
Development and use of the point and integral forms of Maxwell's equations for static and quasi-static electric and magnetic fields with emphasis placed on the vector nature of these fields. Includes analytic and computational solutions to field's problems. The wave equation for E.M. fields is derived and discussed. Prereq: ELEN 2020, MATH 2450 and PHYS 1004 or PHYS 1014.

ELEN 3120. Electromagnetic Fields 2. 3 cr. hrs.
Development and use of Wave Equations as derived from Maxwell's equations to explain the propagation of electromagnetic waves. Includes treatment of physical optics, antennas, wave-guides and transmission lines. Prereq: ELEN 3110.

ELEN 3210. Electric Drives. 3 cr. hrs.
Application of electromagnetic field and circuit theory to electromechanical energy conversion systems. Solutions for the magnetic fields, electromagnetic and electrostatic induced forces, and equivalent circuits using conservation of energy principles. Operation of electric machinery from solid-state power switch converters. Prereq: ELEN 3110.
ELEN 4015. 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. 2 hrs. lec., 2 hrs. lab. Prereq: Cons. of instr.

ELEN 4090. Developments in Electronics. 1-3 cr. hrs.
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 laser electronics, optoelectronics and photonics, RF circuit design, SOC design. Prereq: Cons. of instr. or Sr. stndg.

ELEN 4110. 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. Receiver architectures and system noise are also introduced and developed. Prereq: ELEN 3120 with a minimum grade of C.

ELEN 4130. Antenna Theory and Design. 3 cr. hrs.
Design and use of antennas of varying types, including wire, broadbands, horn, and reflector antennas in transmitting and receiving applications. The application and design of antenna arrays, and an introduction to diffraction theory. DESIGN ELECTIVE. Prereq: ELEN 3120 with a minimum grade of C.

ELEN 4150. 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. Prereq: ELEN 3110 or equiv.

ELEN 4190. Developments in Electromagnetics. 1-3 cr. hrs.
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 wireless and microwave components and systems, electromagnetic compatibility, radio wave propagation. Prereq: Cons. of instr. or Sr. stndg.

ELEN 4210. 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. Design elective. Prereq: ELEN 2020, ELEN 3110 and ELEN 3210.


ELEN 4230. 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. Design elective. Prereq: ELEN 2020 and ELEN 3020.

ELEN 4240. 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. Design elective. Prereq: ELEN 2020, ELEN 3110 and ELEN 3210.

ELEN 4250. 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, wavefront flattening techniques and surge arrester design applications for voltage buildup reduction and control are studied. Includes polyphase multi-velocity multiconductor system transients. Design elective. Prereq: ELEN 2020 and ELEN 3110.
ELEN 4290. 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. Prereq: Cons. of instr. or Sr. stndg.

ELEN 4310. 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. Design Elective. Prereq: ELEN 3020 or BIEN 3300.

ELEN 4320. 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. Design Elective. Prereq: ELEN 3020 or BIEN 3300.

ELEN 4390. Developments in Control. 1-3 cr. hrs.
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 optimal, adaptive and robust control methods, digital control and nonlinear systems. Prereq: Cons. of instr. or Sr. Stndg.

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. Prereq: EECE 3010, ELEN 3110 and PHYS 1004 or PHYS 1014.

ELEN 4450. Surface Acoustic Wave Devices. 3 cr. hrs.
This course is concerned with the theory and applications of surface acoustic wave devices. Major topics covered include: theory of surface and other acoustic wave modes; design, analysis, and performance of interdigital devices; SAW bandpass filters; oscillators and sensors; and applications of SAW devices in wireless communications. Design Elective. Prereq: ELEN 3020 (or BIEN 3300) and ELEN 3110; or cons. of instr.

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. Design Elective. Prereq: Sr. stndg.

ELEN 4490. Developments in Devices. 1-3 cr. hrs.
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 optoelectronic devices, nano-scale devices, solid-state devices, integrated electronic devices, power devices, electro-mechanical devices, quantum devices. Prereq: Cons. of instr. or Sr. stndg.

ELEN 4550. Developments in Signal Processing. 1-3 cr. hrs.
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. Prereq: Cons. of instr. or Sr. stndg.

ELEN 4560. 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. Prereq: ELEN 3020 or BIEN 3300.

ELEN 4565. Optical Fiber Communications. 3 cr. hrs.

ELEN 4570. 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. Design Elective. Prereq: ELEN 3020 (or BIEN 3300) and ELEN 3110.

ELEN 4590. Developments in Communications. 1-3 cr. hrs.
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 digital modulation and detection, coding theory, information theory. Prereq: Cons. of instr. or Sr. stndg.
ELEN 4920. Principles of Design. 3 cr. hrs.
Course content focuses on a structured product design and development process that includes project definition, customer needs identification, product specification, concept generation, and concept selection. Course also focuses on issues related to teamwork, project management, and effective communication. Student team design projects culminate in the development of a technically and economically viable concept and a proposal for future development of this concept (done in the second semester of this two-course sequence). 2 hrs. lec., 1 hr. disc. Prereq: Sr. stndg.; Co-op students, jr. stndg. Cross-listed with BIEN 4920, COEN 4920 and MEEN 4920.

ELEN 4995. Independent Study in Electrical Engineering. 1-4 cr. hrs.
Undergraduate independent study project of either a theoretical or experimental nature. Prereq: Jr. stndg., 3.000 GPA, cons. of instr., and cons. of dept. ch.

ELEN 4998. Senior Design Project. 3 cr. hrs.
Focuses on detailed design, prototyping, and testing design concepts. Includes topics directly relevant to student design projects and careers in the engineering profession. Student team design projects culminate in a final report that documents the performance and details (engineering drawings and/or documentation) of their final design. 2 hrs. lec., 1 hr. disc. Prereq: ELEN 4920. Cross-listed with BIEN 4998, COEN 4998 and MEEN 4998.