Department of Electrical and Computer Engineering

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Associate Professors:	Awad, Mariette; Bazzi, Ali; Costantine, Joseph; Saghir, Mazen; Tawk, Youssef; Karameh, Fadi; Kanj, Rouwaida; Zaraket, Fadi
Assistant Professors:	Daher, Naseem; Issa, Ibrahim; Nassif, Roula
Adjunct Professor:	Khoury, Shahwan
Senior Lecturers:	Chahine, Hazem; Hamandi, Lama; Huijer, Ernst
Lecturers:	Droubi, Ghassan; Hijazi, Basma; Marmar, Ali; Moukallid, Ali
Instructors:	Dinnawi, Rafica; Kanafani, Zaher; Kanso, Ali

Graduate Programs

The Department of Electrical and Computer Engineering offers the degree of Master of Engineering (ME) in Electrical and Computer Engineering and the degree of Doctor of Philosophy (PhD) in Electrical and Computer Engineering.

Master of Engineering in Electrical and Computer Engineering

The ME program (ME) degree with two options: A non-thesis and a thesis option. The ME degree develops future engineering professionals who drive innovations, conduct research, and advance technology for a successful career in industry and academia.

- ECE Thesis Program
- ECE Non-Thesis Program
- Information and Communications Technology Program (EICT)

All programs must satisfy either the thesis program requirements or the non-thesis program requirements. The program is indicated on the student's transcript. Accepted students normally are eligible for Graduate Fellowship and Assistantship Program (GFAP) and Graduate Research Assistant (GRA). Refer to the General University Academic Information section.

Requirements

All relevant requirements and regulations of the university and the Maroun Semaan Faculty of Engineering and Architecture for the master's degree apply to the ME in ECE

programs.

In order to be eligible for admission, a student must have a bachelor's degree from an accredited university.

Students whose undergraduate degree is in an area other than engineering and students whose undergraduate degree is a three-year degree are considered prospective graduate students. The supplementary courses must be completed within four consecutive regular terms.

Master's Thesis Program Requirements (30 cr.)

- 24 course credit hours of which
  - a minimum of 21 credits of graduate level courses
  - a minimum of 18 credits of ECE courses
  - a minimum of 9 credits of graduate level in the major area
- 6 credits for master's thesis
- the seminar course (should be registered for a minimun of 2 terms)
- Students have to declare their major area by the end of the registration period of their last term.

Note: A student may declare a minor area after registering for at least two courses in the area.

Master's Non-Thesis Program Requirements (33 cr.)

- 33 credit hours in graduate courses
  - a minimum of 24 credits of ECE courses
  - a minimum of 12 graduate credits in the major area
- the seminar course (should be registered a minimum of 2 terms)
- Students have to declare their major area by the end of the registration period of their last term.

Note: A student may declare a minor area after registering for at least two courses in the area.

Information and Communications Technology Program

The Information and Communications Technology (EICT) Program is consistent with the requirements for the ME in ECE thesis program and consists of 30 credits distributed as follows:

- 15 credits in core courses
- 9 credits in elective courses
- an internship (no credits) with a minimum duration of 10 weeks and a maximum duration of six months
- 6 credits for the master's thesis
- the seminar course (should be registered minimum 2 terms)

The courses are divided into three areas that are software systems, telecommunications and business/management. The 15-credit core courses should satisfy the following conditions:

- 6 credits in software systems selected from a set of core courses
- 6 credits in telecommunications selected from a set of core courses

- 3 credits in business/management selected from a set of core courses

The 9 credits in elective courses should satisfy the following conditions:

- one regular 3-credit course from either the software systems elective pool or the telecommunications elective pool
- one regular 3-credit course from the business/management elective pool
- one graduate level lab course and two technical special courses, constituting the remaining 3 credits

All elective courses should be taken from the three defined pools of elective courses (software systems pool, telecommunications pool and business/management pool).

Core Courses

- **Software Systems:** EECE 633, EECE 652 and EECE 696
- **Telecommunications:** EECE 640, EECE 643, EECE 651, EECE 653, EECE 655 and EECE 656
- **Business/Management:** DCSN 330, INFO 300, INFO 310, INFO 315, INFO 320 and INFO 330

Elective Courses

- **Software Systems:** EECE 623, EECE 631, EECE 633, EECE 634, EECE 636, EECE 637, EECE 638, EECE 639, EECE 652 and EECE 696
- **Telecommunications:** EECE 640, EECE 641, EECE 642, EECE 643, EECE 644, EECE 645, EECE 646, EECE 647, EECE 651, EECE 653, EECE 655, EECE 656, EECE 680 and EECE 681
- **Business/Management:** DCSN 330, INFO 300, INFO 310, INFO 315, INFO 320, MKTG 306, ENMG 654, ENMG 656 and ENMG 657
- **Lab Courses:** EECE 640L, EECE 651L, EECE 655L, EECE 691L and EECE 694L

Major and Minor Areas

The major and minor areas for the ME and PhD in ECE programs are shown below with their corresponding courses.

- **Applied Electromagnetics and RF Systems:** EECE 680, EECE 681, EECE 682, EECE 683, EECE 684, EECE 685, EECE 686, EECE 687
- **Artificial Intelligence and Machine Learning:** EECE 633, EECE 634, EECE 639, EECE 664, EECE 667, EECE 668, EECE 690, EECE 693, EECE 699
- **Biomedical Engineering:** EECE 601, EECE 603, EECE 605
- **Communications and Signal Processing:** EECE 640, EECE 641, EECE 644, EECE 645, EECE 646, EECE 691, EECE 692, EECE 694, EECE 695
- **Computer Hardware Systems:** EECE 612, EECE 616, EECE 617, EECE 621, EECE 622, EECE 623, EECE 624, EECE 625, EECE 626
- **Computer Software Systems:** EECE 631, EECE 636, EECE 637, EECE 638, EECE 642, EECE 652, EECE 696, EECE 731, EEE 732
- **Control Systems:** EECE 660, EECE 661, EECE 662, EECE 663, EECE 665, EEE 669, EECE 697, EECE 698
- **Energy and Power Systems:** EECE 670, EECE 671, EECE 672, EECE 673, EECE 674, EECE 675, EECE 676, EECE 678, EECE 679
- **Networks and Security:** EECE 632, EECE 635, EECE 647, EECE 651, EECE 653, EECE 655, EECE 656, EECE 657

PhD in Electrical and Computer Engineering

Mission

The PhD program in ECE creates knowledge through advanced coursework and original research with expert faculty to shape the next generation of leaders for careers in academia and industry. It provides students with research-intensive studies in the different areas of ECE to develop competencies and proficiency in emerging technologies, and the latest advancements in science and engineering

Objectives

The objectives of the program are to:

- provide students with research opportunities to acquire an in-depth of knowledge in one specialization area of electrical and computer engineering and familiarity with allied areas,
- provide opportunities for doctoral students to develop competence in performing independent research, communicating effectively and learning independently,
- advance the state of electrical and computer engineering research at AUB, in Lebanon and in the region,
- and advance state of the art in electrical and computer engineering.

Program Outcomes

Graduates of the program are expected to have:

- breadth of knowledge in electrical and computer engineering and depth of knowledge in their specific area of research,
- an ability to identify and define research problems,
- experience in performing research and communicating the results effectively,
- experience in doing independent academic work,
- and a published contribution to the existing literature in electrical and computer engineering.

Applicants who have an excellent record of academic achievement and potential for creative and independent work may be admitted into one of the following categories:

- Students Holding a Master's Degree
- Students Holding a Bachelor's Degree
- The minimum admission requirements for the two categories are described below.

Admission Requirements for Students Holding a Master's Degree

Applicants to the PhD program must hold a master's degree in Electrical and Computer Engineering or a related discipline from AUB or another recognized institution of higher education, with a minimum cumulative average of 85 (3.7) over 100 or its equivalent. Admission is determined by evaluating the following:

- Academic transcripts from the institution(s) of higher education attended by the applicant

- Graduate Record Examination (GRE) general test scores
- A written statement of purpose
- Three letters of recommendation
- A portfolio that includes a resume and samples of work
- An interview conducted with the ECE Graduate Committee (EGC) in person, by phone or over the Internet
- Satisfaction of the university requirements for admission to PhD programs

Program Requirements for Students Holding a Master's Degree

Completion of at least 48 credits of graduate study consisting of combined course work and research beyond the master's degree is required for the PhD degree in Electrical and Computer Engineering. A minimum of 18 credits of course work and a minimum of 24 credits of research and thesis work are required.

The basic program of study for the PhD degree is built around one major area and at least one minor area. Students take courses to satisfy the major and minor area requirements and acquire the knowledge needed for the written and oral examinations.

- The major area has to be in one of the ECE areas.
- Students must take at least 4 graduate courses, including courses prior to admission to the PhD program, in their PhD major area.
- Students must also take at least 2 graduate courses in their PhD minor area, including courses taken prior to admission to the PhD program.
- The minor courses have to be from one of the ECE areas.

Students must maintain a cumulative average of 85 (3.7) over 100 in order to remain in good standing. The cumulative average is calculated for courses taken beyond the master's degree. Students will be placed on probation if they fail a course (below C+ or 70) or have a cumulative average that falls below 85 (3.7). In such cases, students have one term to raise their cumulative average to a minimum grade of 85 (A-) and have to repeat failed courses as soon as the concerned courses are offered. Failure to do so will result in academic dismissal. Students cannot earn a PhD with a cumulative average below 85 (3.7).

PhD Qualifying Exam for Students Holding a Master's Degree

Refer to the General University Academic Information section.

Qualifying Exam Part I: Comprehensive Exam for Students Holding a Master's Degree

After taking at least 15 credits of coursework and mastering the knowledge delineated in the PhD major area, students take the Qualifying Exam Part I: Comprehensive Exam. The exam is given twice a year at the end of the fall and spring terms. Students are informed beforehand of the subjects that will be covered in the examination. Students who do not pass may repeat the exam only once during the following term. If students do not pass the exam after their second attempt, they will be asked to discontinue their PhD studies.

Students sit for two exams that together constitute the comprehensive examination with one in the major area and one in the minor area. These two exams are taken separately at different times during the same examination period. The major area exam consists of eight questions, out of which five questions should be answered in four hours. The minor area exam consists of six questions, out of which three questions should be answered in two and a half hours. The area exams are prepared by the corresponding area faculty committee and are designed to evaluate the student's understanding of the fundamentals in the area. Passing the comprehensive exam requires an average of no less than 3.2 or 80 over 100, with no less than 3.2 or 80 over 100 in the major area and no less than 2.2 or 70 over 100 in the minor area. Refer to the General University Academic Information section.

Admission to Candidacy for Students Holding a Master's Degree

Students must be admitted to candidacy at least two terms before obtaining the PhD degree.

For admission to candidacy, students are expected to have:

- submitted a program approved by the thesis committee, ECE Graduate Committee (EGC), MSFEA Graduate Studies Committee (GSC) and Graduate Council (GC),
- passed the Qualifying Exam Part I and II,
- completed at least 12 credits of graduate courses beyond the master's degree,
- attained a cumulative average of at least 85 (3.7) in all courses taken beyond the master's degree,
- and maintained good academic standing.

Residence Requirements for Students Holding a Master's Degree

A student must register for at least four terms beyond the completion of the master's degree. Requirements for the PhD degree must be completed within a period of ten regular terms years after starting graduate work beyond the master's degree. Extension beyond the five-year limit requires the approval of the EGC, MSFEA GSC and GC.

Admission Requirements for Students Holding a Bachelor's Degree (Accelerated PhD Track)

- A bachelor's degree with a minimum major and cumulative average of 85 (3.7) over 100 or its equivalent in Electrical and Computer Engineering
- Graduate Record Examination (GRE) general test scores
- Three letters of recommendation (one from the FYP supervisor)
- An applicant's written statement of purpose that shows the research potential in the proposed area of study
- A two-three page research proposal
- Performance of the candidate in the EECE 499 research-based course if taken or a proven research record through published articles
- An interview conducted with the ECE Graduate Committee (EGC) in person, by phone or over the Internet

Course Requirements for Students Holding a Bachelor's Degree

The completion of at least 78 credits of graduate study consisting of combined coursework and research beyond the bachelor's degree is required for the accelerated PhD track in Electrical and Computer Engineering. A minimum of 36 credit hours must be in approved graduate level course work and a minimum of 30 credit hours in thesis work. In addition, normally a maximum of 6 credit hours out of the 36 credits of coursework may be in tutorial courses.

The basic program of study for the accelerated PhD track is built around one major area and a minimum of one minor area. Students take courses to satisfy the major and minor area requirements and to acquire the knowledge needed for the Qualifying Exam Part I and II.

- The major area has to be in one of the ECE areas.
- Students must take at least six graduate level courses in their PhD major area.
- Students must take at least three graduate level courses in their PhD minor area.
- The minor courses have to be from one of the ECE areas.

PhD Qualifying Exam for Students Holding a Bachelor's Degree

Refer to the General University Academic Information section.

Qualifying Exam Part I: Comprehensive Exam for Students Holding a Bachelor's Degree

Comprehensive examinations are written exams taken after completing a minimum of 30 credits of course requirements for the accelerated track. Timing of the examination is set by the department/program no later than the sixth regular term of the PhD student's enrollment. Refer to the General University Academic Information section.

Residence Requirements for Students Holding a Bachelor's Degree

The student must register for at least eight terms beyond the completion of the bachelor's degree. Requirements for the PhD degree in the accelerated track must be completed within a period of twelve regular terms after starting graduate work beyond the bachelor's degree. Extension beyond the twelve regular terms limit requires the approval of the EGC, MSFEA GSC and GC.

Students deemed by the department, within one to two years after admission into the accelerated track, as not qualified to complete a PhD degree may be granted a master's degree in the area after completing the equivalence of a non-thesis master's. Every effort will be made to screen students carefully to assure their potential and aptitude as researchers prior to acceptance. This may be accomplished by having selected students participate in ongoing research projects while they are registered undergraduates.

Admission to Candidacy for Students Holding a Bachelor's Degree

Students must be admitted to candidacy at least two terms before obtaining the PhD degree.

For admission to candidacy, students are expected to have:

- submitted a program approved by the thesis committee, EGC, MSFEA GSC and GC
- passed the oral qualifying examination
- completed at least 30 credits of graduate level courses beyond the bachelor's degree
- attained a cumulative average of at least 85 (3.7) in all courses taken beyond the bachelor's degree
- maintained good academic standing

PhD Thesis Committee

In accordance to the Lebanese Ministry of Higher Education, the thesis committee should be composed of at least five faculty members:

- Chair of the committee, advisor and at least one member from the student's department/program
- Two members must be from outside the university
- At least four committee members must be from the student's major area
- All members must hold doctoral degrees
- The advisor and at least three of the members must be of professorial rank
- The chair of the thesis committee must be a full professor and cannot be the advisor

Members of the committee are recommended by the student's thesis advisor and approved by the Graduate Committee of the ECE department, MSFEA Graduate Studies Committee and Graduate Council.

The committee approves the thesis topic and research plan, administers the oral Qualifying Exam (Part II) and conducts the thesis defense. The thesis proposal and selection of the committee should be approved at least two terms before the thesis defense.

Any changes in the committee, including the thesis advisor, must receive the approval of the EGC, MSFEA GSC and GC.

PhD Thesis Proposal

Refer to PhD Thesis Proposal under General University Academic Information section.

Qualifying Exam Part II: Defense of Thesis Proposal

Within two terms of passing the comprehensive examination, the student must take an oral qualifying examination, administered by her/his thesis committee. The defense of the PhD thesis proposal is considered part of the oral qualifying examination. In addition to reviewing the prospectus of the thesis, the nature and content of the examination are related to the student's field of research. Refer to Qualifying Exam Part II: Defense of Thesis Proposal under General University Academic Information section.

PhD Thesis

The student must submit a thesis based on the results of original and independent research. The PhD thesis is expected to make a significant contribution to the field of electrical and computer engineering. Upon its completion and after its approval by the thesis advisor, the thesis must be defended orally. Refer to PhD Thesis Format under General University Academic Information section.

PhD Thesis Defense

Refer to PhD Thesis Defense under General University Academic Information section.

Seminar Requirement

The student must register for the EECE 797 Seminar as long as s/he is enrolled in the program.

Program Completion Requirements

To earn the PhD degree in Electrical and Computer Engineering, the student must complete the following requirements:

- Have at least one journal article, based on the PhD thesis, accepted in a leading international journal in the field of specialty subjected to at least two reviews. Additionally, at least two refereed conference papers based on the thesis must have appeared in conference proceedings.
- Have a cumulative average, beyond the master's degree, of 85 (3.7) or above and be in good academic standing.
- Satisfy the course and research credit requirements.
- Pass the comprehensive and oral qualifying examinations.
- Complete and successfully defend a PhD thesis.
- Satisfy the residence requirement and all other pertinent AUB regulations.

PhD Major or Minor Areas

The PhD major or minor areas of study with their corresponding courses are the same as those listed for the master's degree (page 386).

Course Descriptions

EECE 601 Biomedical Devices and Equipment 3 cr.
The course discusses the main types of biomedical devices and equipment in terms of the physical principles underlying their operation, their operational characteristics, and their applications. The discussion includes: ultrasound systems, blood instruments, cardiac and respiratory devices and equipment, clinical laboratory equipment, radiology equipment. X-ray machines, CT scanners, PET scanners, and magnetic resonance imaging systems.*Prerequisites: BIOL 210 or BIOL 202 or PHYL 246; and EECE 210 or PHYS 228 and PHYS 228L; or consent of the instructor.*

EECE 603 Biomedical Signal and Image Processing 3 cr.
Fundamentals of digital signal processing as implemented in biomedical applications. It provides a concise treatment of the tools utilized to describe deterministic and random signals as the basis of analyzing biological signals: data acquisition, imaging, denoising and filtering, feature extraction, modeling. The course is tightly coupled with a practical component through laboratory projects. Examples include the auditory system, speech generation, electrocardiogram, neuronal circuits and medical imaging. Students should have reasonable software skills in Matlab. *Pre or co-requisites: STAT 230 and EECE 340, or STAT 233 and EECE 340 or consent of instructor.*

EECE 605 Neuromuscular Engineering 3 cr.
An introduction on the nervous system, electrophysiology and chemical kinetics. The cell membrane in the steady state: resting membrane voltage and membrane equivalent circuit. Generation and propagation of the action potential: Hodgkin-Huxley model, properties and propagation of the action potential. Synapses: neuromuscular junction, fast chemical synapses, second-messenger systems, synaptic plasticity and electrical synapses. Neurons: neuronal currents, firing patterns and signaling in dendrites. Muscle: contraction, mechanics and receptors. Control of movement: mechanics, spinal reflexes, hierarchical organization and control, locomotion, equilibrium-point hypothesis. *Prerequisites: BIOL 210 or BIOL 202 or PHYL 246, and EECE 210; or PHYS 228, PHYS 228L and MATH 202; or consent of instructor.*

EECE 612/412 Digital Integrated Circuits 3 cr.
A course on digital electronic circuits; models, current equations, and parasitics of CMOS transistors for digital design; study of CMOS inverter and logic gates, including analysis, design, simulation, layout, and verification; advanced circuit styles; sequential circuits; advanced topics: semiconductor memories, power grid, clocking strategies, data-path building blocks, deep-submicron design issues, interconnect. *Prerequisites: EECE 310 and EECE 320, or consent of instructor.*

EECE 616 Advanced Digital Integrated Circuits 3 cr.
This course covers advanced concepts in circuit design for digital VLSI systems in state of-the-art integrated circuits technologies. Emphasis is on circuit design and optimization techniques targeted for high-speed, low-power or high-density circuits. The impact of scaling, deep submicron effects, interconnect, signal integrity, power distribution/ consumption and timing on circuit design is investigated. Emerging challenges in low power/low voltage design, process variations and memory design in the nano-scale era are covered. *Prerequisite: EECE 412 or EECE 612 or consent of instructor.*

EECE 617 Reliability and Statistical Design 3 cr.
This course explores major aspects of statistical design methodologies with particular emphasis on electrical and computer engineering problems. It covers various topics in the domain of reliability, yield estimation, variance reduction methods for purposes of extreme statistics and rare fail event estimation, modeling and optimization. Case studies will be provided to analyze the manufacturability challenges of advanced circuits and the implications on low power design.

EECE 621 Advanced Computer Architecture 3 cr.
This course focuses on modern advancements in parallel computer architecture with emphasis on instruction level parallelism (ILP). Topics include: advanced branch prediction, data speculation, memory dependence prediction, trace caches, dynamic optimization, checkpoint architectures, latency-tolerant processors, simultaneous multithreading, speculative multithreading and virtual machines. A key component of the course is a research project in which students use architecture performance simulator to investigate novel architecture techniques. *Prerequisite: EECE 421 or consent of instructor.*

EECE 622 VLSI for Communications and Signal Processing 3 cr.
This course introduces concepts in the design and implementation of digital signal processing systems using integrated circuits. Emphasis is on the architectural exploration, design and optimization of signal processing systems for communications. Algorithm, architecture and circuit design techniques are introduced that enable joint optimization across the algorithmic, architectural and circuit domains. A key component of the course is a project in which students investigate problems in the design and implementation of low-power and high-performance communication systems. *Prerequisite: EECE 491 or EECE 691 or consent of instructor.*

EECE 623/423 Reconfigurable Computing 3 cr.
A course on reconfigurable computing systems and applications; contemporary FPGA architectures; FPGA design flows and tools; high-level synthesis; hardware/software partitioning; host, memory and peripheral interfaces; operating system support; dynamic partial reconfiguration; classical and emerging applications. Students work on a set of design assignments and a research project using appropriate FPGA development boards and tools. *Prerequisite: EECE 321 or consent of instructor.*

EECE 624 Digital Systems Testing 3 cr.
This course covers an overview of digital systems testing and testable design; test economics, fault modeling, logic and fault simulation, testability measures; test generation for combinational circuits; memory test; delay test; IDDQ test; scan design and boundary scan. *Prerequisite: EECE 320 or consent of instructor.*

EECE 625/425 Embedded Systems Design 3 cr.
A course on contemporary embedded systems design. The system design process; microcontroller architectures and programming; standard peripheral device controllers (GPIO, timers/counters, interrupts); serial interfaces (RS232, SSI/SPI, I2C, USB); displays; memory devices and DMA; IoT and network interfaces; analog/digital conversion; pulse-width modulation; motor control; embedded operating systems. Students work on a set of design assignments and a major project using appropriate microcontroller development boards and tools. *Prerequisite: EECE 321 or consent of instructor.*

EECE 626 Hardware Accelerators for Machine Learning 3 cr.
This course provides an in-depth coverage of architectural techniques used to design accelerators for training and inference in machine learning systems, with focus on recent advances towards enabling efficient processing of DNNs. It provides an overview of DNNs, discusses various hardware platforms and architectures that support DNNs, and highlights key trends in reducing the computational cost of DNNs via hardware design changes only or through joint hardware design and DNN algorithm optimizations. It also covers various development tools that enable students to quickly get started in this field, and highlights important benchmarking metrics and design considerations to be used for evaluating a plethora of DNN hardware design options. Case studies include Google's TPU, Apple's Neural Engine, Intel's Nervana processor, and ARM's Project Trillium. The course involves a semester project that focuses on developing architectures for hardware ML accelerators. *Prerequisites: EECE 490 and EECE 420 or EECE 421, or consent of instructor.*

EECE 631 Advanced Topics in Algorithms 3 cr.
This is a second course on algorithms. The aim of the course is to cover general tools from probability and convex optimization with applications to randomized algorithms, approximation algorithms, and theoretical computer science in general. Topics include: introduction to randomized algorithms, tail inequalities, probabilistic method, random walks, hashing, derandomization, introduction to approximation algorithms, basics of linear programming, algorithms for solving linear programs, linear programming relaxation and approximation algorithms, basics of semidefinite programming, semidefinite relaxation and approximation algorithms, interior point methods, and selected topics as time permits. *Prerequisites: EECE 431 or EECE 331 and STAT 230 or STAT 233 and MATH 218 or MATH 219 or consent of instructor.*

EECE 632/ 455 Cryptography and Network Security 3 cr.
This course provides an overview of encryption and network security. The topics include: classical encryption techniques, block ciphers and the data encryption standard, finite fields, advanced encryption standard, confidentiality using symmetric encryption, public-key cryptography, key management, hash and MAC algorithms, digital signatures, authentication applications, Web security, email security and IP security.

EECE 633 Data Mining 3 cr.
This course is an introduction to data mining. Data mining refers to knowledge discovery, using huge amounts of data to arrive at non-trivial conclusions. Topics will range from statistics to machine learning to database, with a focus on analysis of large data sets. The course will target at least one new data mining problem involving real data, for which the students will have to find a solution. *Prerequisite: EECE 330 or consent of instructor.*

EECE 634 Introduction to Computational Arabic 3 cr.
The course discusses computational challenges specific to the Arabic language including representation, rendering, processing, structure, interface and recognition. The course also discusses multilingual texts with Arabic, visits text processing techniques such as encoding, matching, tokenization, search, indexing and pattern matching. The course reviews the state of the art in automating Arabic language understanding. *Prerequisite: EECE 330 or consent of instructor.*

EECE 635 Theoretical Foundations of Security and Privacy 3 cr.

This course provides a rigorous framework to study security and privacy using suitable mathematical models. Such models enable the assessment of the security/privacy guarantees of a given system, including communication and computing systems and databases. In particular, this course covers both computational and information-theoretic notions of security and privacy. Students learn various adversarial models and their corresponding information-theoretic measures, in addition to basic cryptographic principles and protocols. Topics include: the Shannon cipher system, one-time pads and perfect secrecy, semantic security and the RSA algorithm, equivocation, and guessing entropy (and other measures). A particular focus is given to the notion of differential privacy and its applications. *Prerequisite: EECE 330 and STAT 230 or STAT 233 or consent of instructor.*

EECE 636 Logic Verification and Synthesis 3 cr.
The course discusses the correctness of logic systems whether software or hardware, the basic representations of propositional logic and first order logic. It discusses how expressive and realizable different logic theories are. It covers tools that reason about the correctness of logic and that automatically synthesize logic into an implementation. *Prerequisite: EECE 330 or consent of instructor.*

EECE 637 Advanced Programming Practice 3 cr.
This is an advanced course on programming practices with a focus on verification. Teams will work in agile and extreme programming environments and will use formal specifications, design patterns and aspect-oriented programming. Projects will involve tools for source control, debugging, code building, documentation, dynamic and static verification. *Prerequisite: EECE 330 or consent of instructor.*

EECE 638 Software Testing 3 cr.
The course focuses on concepts, techniques and tools for testing software. It provides practical knowledge of a variety of ways to test software and an understanding of some of the tradeoffs between testing techniques. The topics include: software testing at the unit, module, and system levels; functional and structural testing; regression testing; mutation testing; test suite minimization and prioritization; automatic test case generation.

EECE 639 Advanced Data Mining 3 cr.
A course that covers advanced topics in data mining and recent progress in this field. Discussions will include which techniques fit best for complex applications in data mining. Mining complex data will include general text mining, Arabic text mining, social network analysis, spatial data mining, mining of the World Wide Web, stream data, time-series data and sequence data. We will also discuss recent application sectors and trends in data mining such as for the telecommunication, biological, and financial sectors. *Prerequisites: EECE 330 and one of the following: EECE 633, EECE 667 or EECE 693; or consent of instructor.*

EECE 640 Advanced Data Mining 3 cr.
A course that covers the fundamentals of wireless communications with emphasis on wireless channel modeling; digital modulation in wireless channels; diversity techniques; channel coding and interleaving in fading channels; adaptive equalization; multiple access techniques; the cellular concept; overview of current wireless communications systems. *Prerequisite: EECE 442 or consent of instructor.*

EECE 640L Wireless Communications Laboratory 1 cr.
A laboratory course that covers the following topics: basics of radio network planning and optimization, radio network planning for the GSM cellular system, radio network planning for the UMTS cellular system, GSM-UMTS co-existence and co-citing, radio network planning for the WiMAX broadband system, indoor GSM drive testing measurements and analysis, outdoor GSM drive testing measurements and analysis, UMTS drive testing measurements and analysis, and measurement-based wireless channel modeling. *Prerequisite: EECE 640 or consent of instructor.*

EECE 641 Information Theory 3 cr.
In this course students study data transmission through introducing the field of information theory. The theory is introduced in a gradual fashion and students study its application to communications theory, computer science, statistics and probability theory. Covering all the essential topics in information theory, students are introduced to the basic quantities of entropy, relative entropy and mutual information to show how they arise as natural answers to questions of data compression, channel capacity, rate distortion and large deviation theory. *Prerequisite: STAT 230 or STAT 233 or EECE 442, or consent of instructor.*

EECE 642 Introduction to Coding Theory 3 cr.
This course introduces the theory of error-correcting codes with a focus on the asymptotic, algorithmic and algebraic aspects. Topics include: background material from combinatorics and algebra; Shannon's coding theorem; linear codes; coding bounds; classical algebraic codes: Hamming and Hadamard codes, Reed-Solomon codes and Justesen codes and decoding algorithms; codes from graphs: low density parity check codes, expander codes, explicit constructions and decoding algorithms; and an introduction to turbo codes.

EECE 644 Stochastic Processes, Detection, and Estimation 3 cr.
This is a graduate-level introduction to the fundamentals of detection and estimation theory involving signal and system models in which there is some inherent randomness. The concepts that we develop are extraordinarily rich, interesting and powerful, and form the basis for an enormous range of algorithms used in diverse applications. The material in this course constitutes a common foundation for work in the statistical signal processing, communication and control areas. *Prerequisites: STAT 230 and EECE 340 or STAT 233 and EECE 340 or consent of instructor.*

EECE 645 Wireless Cellular Technologies 3 cr.
A course on the evolution of cellular technologies with focus on 2G GSM technology, 3G UMTS/HSPA technology, 4G LTE technology and beyond. Topics include: cellular network fundamentals; standardization; transmitter and receiver link level designs; access and core network architectures; physical channels and signaling procedures; scheduling and radio resource management; radio network planning; multiple antenna techniques; emerging topics. *Prerequisite: EECE 640 or consent of instructor.*

EECE 646 Advanced Digital and Data Communications 3 cr.
A course that addresses digital communication principles and techniques aimed at achieving improved reliability. The course examines information measures, such as entropy and mutual information for discrete and waveform channels, source coding, channel capacity and coding theorem, linear block and cyclic codes, hard and soft decision decoding, and spread spectrum modulation. *prerequisite: consent of the instructor.*

EECE 647 Queuing Theory 3 cr.
A course that covers Poisson counting and renewal processes; Markov chains and decision theory, branching processes, birth death processes and semi-Markov processes; simple Markovian queues, networks of queues, general single and multiple-server queues, bounds and approximations.

EECE 651 Internet Engineering 3 cr.
A course that provides in-depth coverage of Internet architecture, Internet protocols and routing; discusses recent developments on the Internet such as IPv6, switching and mobility; and gives a detailed study of TCP. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 651L Internetworking Laboratory 1 cr.
This laboratory course covers the technologies and protocols of the Internet. The experiments cover IP, ARP, ICMP, UDP, TCP, DNS, routing protocols (RIP, OSPF, BGP), network address translation (NAT), dynamic host configuration (DHCP), SNMP and IP multicast. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 652 Web Server Design and Programming 3 cr.
This course concentrates on major technologies used in building web servers. It is divided into two parts: client programming and server programming. The first part includes HTML, CSS, Java Script and XML programming. The second part is based on the ASP. NET framework (both Forms and MVC) along with C#. It covers basic controls, validation, database interfacing, AJAX, sessions and cookies, file uploading and downloading, emails with attachments, securing websites, user controls and third-party controls. The course concludes with programming and interfacing with web services. The website development group-based project is a major component of the course.

EECE 653 Multimedia and Networking 3 cr.
This course covers topics in multimedia such as system requirements, performance requirements, representation and compression. Multimedia networking is emphasized by discussing multicasting, streaming, multimedia networking protocols and quality of service-based traffic management protocols. Other topics covered include synchronization, VoIP and Internet2. Multimedia networking applications are designed and implemented as student projects. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 655 Internet Security 3 cr.
The course covers topics in Internet security. It discusses security threats, vulnerabilities of protocols and the different types of attacks. Preventive and defensive mechanisms are covered, such as e-mail security, web security, IP security, network management security, wireless security, intrusion detection techniques, firewalls, VPNs and tracing the source of attacks. Student projects will be composed of implementation, simulation and research components. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 655L Network and Computer Security Laboratory 1 cr.
A laboratory that addresses advanced network and computer security topics. Experiments include the execution of attacks, the setup of intrusion detection and prevention, securing computers and wired and wireless networks, and digital forensics. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 656 Mobile Ad Hoc and Sensor Networks 3 cr.
This course covers major aspects of ad hoc and sensor networking, and tackles topics related to mobility, disconnections and battery energy consumption. The course is composed of two parts: mobile ad hoc networks (MANETs) and wireless sensor networks (WSNs). The first part provides a detailed treatment of routing protocols in MANETs, the changes to TCP to support mobility and vehicular networks. In the second part, topics covered concern information-centric routing, MAC layer provisions for energy savings, addressing, localization, time synchronization and information dissemination. The group project gives students hands-on experience in designing protocols and applications for real sensor devices. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 657 Wireless Security 3 cr.
A course that covers wireless network security; security challenges in wireless networks; security problems facing existing and upcoming wireless networks; security in naming, addressing, neighbor discovery and routing; and trust and privacy. *Prerequisites: EECE 350 or EECE 351 and EECE 455 or EECE 632, or consent of instructor.*

EECE 660/ MECH 653 **System Analysis and Design** **3 cr.**

A course that outlines state-space models of discrete and continuous, linear and nonlinear systems; controllability; observability; minimality; Eigenvector and transforms analysis of linear time invariant multi-input multi-output systems; pole shifting; computer control; design of controllers and observers. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 661/ MECH 641 **Robotics** **3 cr.**

Robotic manipulators classification and work envelope. Robot kinematics, dynamics and forces. Joints trajectory planning for end effector desired tracking and constrained motion. Control of robots using linear, nonlinear and adaptive controllers. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 662/ MECH 655 **Optimal Control** **3 cr.**

A course on optimization theory and performance measures, calculus of variations, the maximum principle, dynamic programming, numerical techniques, LQR control systems.

EECE 663/ MECH 656 **System Identification** **3 cr.**

This course introduces the basic mathematical tools to fit models into empirical input-output data. General time-series modeling and forecasting, such as stock prices, biological data and others. Topics include nonparametric identification methods: time and frequency response analysis; parametric identification: prediction error, least squares, linear unbiased estimation and maximum likelihood; convergence, consistency and asymptotic distribution of estimates; properties and practical modeling issues: bias distribution, experiment design and model validation.

EECE 664 **Fuzzy Sets, Logic and Applications** **3 cr.**

A course that outlines fuzzy sets and related concepts; logical connectives; mapping of fuzzy sets; extension principle; fuzzy relations and fuzzy set ordering; fuzzy logic inference; applications: fuzzy control, signal processing, pattern recognition, decision-making and expert systems.

EECE 665/ MECH 654 **Adaptive Control** **3 cr.**

A course that includes the control of partially known systems; analysis and design of adaptive control systems; self-tuning regulators; model reference adaptive control of uncertain dynamic systems; typical applications. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 667 **Pattern Recognition** **3 cr.**

The course provides an overview of the algorithms used in machine learning. The course discusses modern concepts for model selection and parameter estimation, decision-making and statistical learning. Special emphasis will be given to regression and classification for supervised modes of learning. Students will be assigned typical machine learning problems to investigate as projects.

EECE 668 Game Theory and Decision-Making 3 cr.
This course provides a set of tools, approaches and perspectives on game theory to mimic the human elements of decision-making that is best described by strategy and cooperation. Topics covered include: games of skills, games of chance, cooperative, mixed motive, zero sum, coalition and repeated games. Students will be assigned real-world examples of game theory to investigate as projects.

EECE 669/ MECH 648 Nonlinear Systems: Analysis, Stability and Control 3 cr.
A course that presents a comprehensive exposition of the theory of nonlinear dynamical systems and its control with particular emphasis on techniques applicable to mechanical systems. The course will be punctuated by a rich set of mechanical system examples, ranging from violin string vibration to jet engines, from heart beats to vehicle control, and from population growth to nonlinear flight control. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 670 Power System Planning 3 cr.
The course investigates electric energy and peak demand forecasts using weather sensitive, time curve, autoregressive and causal models; generation reliability evaluation, loss of energy expectation, energy limited units, probabilistic production costing, generating capacity expansion analysis and maintenance scheduling; operational planning, unit commitment, hydrothermal coordination; power system security classification, contingency analysis, external equivalents, optimal power flow; planning in a competitive electric power environment. *Prerequisite: EECE 471 or consent of instructor.*

EECE 671 Environmental Aspects of Energy Systems 3 cr.
A course that examines world energy resources and classifications; sources and effects of air pollution; air quality modeling, Gaussian dispersion models for pollution estimation; motor vehicle emissions and noise pollution; environmental impacts of electricity generation, pollution control systems, electromagnetic radiation, production and impacts in high-voltage applications; environmental impact assessment; basic concepts.

EECE 672 Energy Planning and Policy 3 cr.
This is a course that focuses on features of modern energy planning and policy. Topics covered include the interaction among the technological, economic, environmental and sociopolitical aspects of energy supply and use; electricity, oil and gas industries, and their market structures; elements of energy planning on the sector and national levels; energy decision-making under conditions of uncertainty; risk management in energy planning; liberalization of energy markets; case studies.

EECE 673 Power Electronics Systems and Applications 3 cr.
A course that reviews converter topologies for AC/DC, DC/AC and DC/DC; power supply applications; converter applications to motor drives; utility interface of distributed energy systems; static VAR systems; flexible AC transmission; high voltage DC; power quality control; active and passive harmonics compensation. *Prerequisite: EECE 473 or EECE 471, or consent of instructor.*

EECE 674 Energy Storage and Sustainable Systems 3 cr.
The course covers the principles of sustainable energy systems, solar radiation, solar thermal applications, the Stirling engine, fuel cells and the hydrogen cycle. Various energy storage technologies are also investigated, e.g. thermal storage, compressed air, flywheels, batteries, and ultra-capacitors. The operation principles of each application will be discussed, its current developments and future trends, and students will design an energy storage solution for a selected application. *Prerequisites: EECE 230, EECE 310 and Phys 210, or consent of instructor.*

EECE 675 PV and Wind Electric Energy Systems 3 cr.
This course seeks to impart in students a sound understanding of renewable energy systems in terms of their design, operation and economic impacts. It covers wind resource assessment and site selection; drag and lift principles; linear momentum theory; turbine characteristics; power and energy yield calculation; aspects of wind drive options: horizontal and vertical axis machines, fixed and variable speed wind turbine generators. It also covers solar resource assessment; photovoltaic cells: photo effect, P-N junction, principle of operation of PV cells, circuit models, maximum power point trackers, I-V and power characteristics, physics of shading, types and characteristics of autonomous solar energy systems, hybrid systems and grid connected systems; the economics of wind and solar energy systems. Introduction to small hydro and geothermal energy systems.

EECE 676 Modeling and Control of Electric Drives 3Cr.
A course that covers several topics related to modeling and control of electric drives. The course introduces fundamental equations related to inductance and flux variations in a rotating machine, leading to torque production. Reference frame theory and transformations are also studied for modeling purposes. Dynamic models of three-phase induction and permanent-magnet synchronous machines are derived. Basic modeling of power electronic converters for electric drives, with focus on three-phase DC/AC inverters, are introduced. Various control strategies are studied with focus on vector control and different power electronic switching schemes in electric drives. *Prerequisite: EECE 474 or EECE 473 or consent of instructor.*

EECE 677 Electric Power System Stability and Control 3 cr.
A course on synchronous machine modeling and simulation, response to small disturbances and voltage instability. Topics include Park's transformation, flux linkage, voltage and state-space equations, subtransient and transient parameters, simplified models of the synchronous machine, treatment of saturation, system reference frame, small-signal stability, power system stabilizers and bifurcation analysis. *Prerequisite: EECE 678 or consent of instructor.*

EECE 678 Advanced Power System Analysis 3 cr.
A course on optimal dispatch of generation, symmetrical components and unbalanced faults, transient stability, control of generation, state estimation in power systems and power system simulation. *Prerequisite: EECE 471 or consent of instructor.*

EECE 679 Energy Efficiency in the Power Sector 3 cr.
Topics covered in the course include: utility companies and energy supply, energy sustainability, cogeneration systems: combined heat and power (CHP) and combined cycle gas turbines (CCGT), reciprocating engines, distributed generation, demand side management, energy analysis techniques, energy audit: types and data analysis, smart grids, energy-efficient rotating machines, design and performance optimization; and case studies. *Prerequisite: EECE 370 or consent of instructor.*

EECE 680 Antennas for Wireless Communications 3 cr.
This course provides students with an understanding of the basic principles of Antenna Analysis and Design for wireless communications. The course covers an overview of the fundamental characteristics and parameters of antennas, an overview of analytical methods used to analyze and design antennas with application to some basic antenna structures such as linear antennas, loop antennas, antenna arrays and microstrip antennas. *Prerequisite: EECE 380 or consent of instructor.*

EECE 681 Advanced Antenna Design 3 cr.
This course provides students with an understanding of advanced antenna structures and presents an overview of analytical and numerical methods used to analyze and design these antenna structures. This course includes broadband antennas, frequency-independent antennas, aperture antennas, horn antennas, microstrip antennas and reflector antennas. Students will work on a research paper on a selected antenna design topic. *Prerequisite: EECE 680 or consent of instructor.*

EECE 682 Time-Harmonic Electromagnetic Fields 3 cr.
A course on time-varying and time-harmonic EM fields; electrical properties of matter; wave propagation and polarization; construction of solutions; reflection and transmission; electromagnetic theorems and principles in particular equivalence; rectangular waveguides and cavities; dielectric, circular and spherical waveguides; radiation from structures; scattering by wedges, cylinders and spheres; radiation from apertures, and perturbational and variational techniques. *Prerequisite: EECE 380 or consent of instructor.*

EECE 683 Numerical Methods in Electromagnetics 3 cr.
This course examines the principles and applications of numerical techniques for solving practical electromagnetics problems. It covers the moment methods, finite difference methods, finite element methods and hybrid methods. The course also investigates the application of the finite-volume control method in electromagnetics. *Prerequisite: EECE 682 or consent of instructor.*

EECE 684 Microwave Engineering 3 cr.
This course focuses on the analysis and design of passive microwave circuits. It covers the fundamentals for radio frequency and microwave engineering. It discusses the theories of transmission lines, waveguides, impedance matching, microwave networks, scattering parameters, power dividers, directional couplers, microwave resonators and microwave filters. The course enables students to study and analyze their own microwave network using computer-aided design tools and measurement equipment. *Prerequisite: EECE 380 or consent of instructor.*

EECE 685 Radio Frequency (RF) Circuits Design 3 cr.
The course focuses on the analysis and design of Radio Frequency circuits and components. The course covers RF design techniques using transmission lines, strip lines, microstrip and coplanar lines. It covers the design of passive and active RF devices, including impedance transformers, amplifiers, oscillators and mixers. It provides understanding of S-parameters and signal-flow graph analysis techniques. The course enables students to get hands-on experience in RF circuit design through the use of computer-aided design tools to simulate and analyze radio frequency circuits, build them as part of a course project, and perform measurements in the lab using network and spectrum analyzers. *Prerequisites: EECE 311, EECE 340 and EECE 380; or consent of instructor.*

EECE 686 Radio-Frequency (RF) Transceiver Design (3 cr.)
This course targets the physical layer of a communication system by focusing on the interactions between the various transceiver blocks. The course addresses the design and operation of the components that reside between the signal processing unit and the antenna within the RF chain. The course also details the functional level modeling of different transceiver architectures by accounting for the gain, noise, nonlinearity, sensitivity and dynamic range. In addition, students are exposed to recent computer-aided simulation tools and measurement techniques through a set of laboratory experiments that are tailored based on the course content. As a result, the course equips the students with theoretical and practical experience in RF transceiver. *Prerequisites: EECE 380 and EECE 311; or consent of instructor.*

EECE 687/487 Radio-Frequency Integrated Circuit (RFIC) Design (3 cr.)
The course addresses the analysis and design of passive and active Radio Frequency Integrated Circuits (RFICs). The course introduces the design of on-chip lumped elements and passive RF components. In addition, it includes the design of various RF blocks such as low noise amplifiers, power amplifiers, oscillators, mixers, phase locked loops, frequency synthesizers, and switches. The course provides students with hands-on experience in the simulation of RFICs as well as the different calibration and de-embedding techniques for on-wafer measurements. As a result, the students will be equipped with essential theoretical and practical experience in RFIC design. *Prerequisites: EECE 380 and EECE 311.*

EECE 690/490 Introduction to Machine Learning 3 cr.
The course provides an overview of machine learning theory and algorithms that learn from experience to predict or control yet to be seen instances. The course discusses the intuition and the theory of some selected modern machine learning concepts as well as practical know-how to successfully apply them to new problems. It covers topics in supervised learning such as parametric/ non-parametric, generative/ discriminative algorithms for classification and regression and in unsupervised learning for clustering, dimensionality reduction and reinforcement learning. The course also includes case studies and applications so that students can gain practice on regularization, model selection, parameter estimation, Bayesian networks, hidden Markov models, support vector machines, reinforcement learning, neural networks and deep learning. Students cannot receive credit for both EECE 664M and EECE 633 and 667. *Prerequisites: EECE 330, and MATH 218 or MATH 219, and STAT 230 or STAT 233 or consent of instructor.*

EECE 691/491 Digital Signal Processing 3 cr.
Digital Signal Processing (DSP) is at the heart of almost all modern technology. This course introduces fundamentals of DSP systems, including digital IIR and FIR filter design, sampling and reconstruction, A/D and D/A conversion, quantization, discrete-time Fourier analysis and fast convolution, spectral analysis, sample-rate conversion, filter structures and realizations, and multirate DSP and filter banks. The course also discusses applications of DSP in areas such as speech/audio processing, autonomous vehicles, and software radio. It includes a project related to DSP algorithm implementation on embedded processors. *Prerequisite: EECE 340 or consent of instructor*

EECE 691L Digital Signal Processing 3 cr.
This graduate lab is comprised of a set of lab experiments in MATLAB, C and Assembly covering a series of real-time signal processing topics. The developed laboratory material is intended to complement the digital signal processing course (EECE 691). Upon completion of the lab, students will have acquired the required knowledge and skills to develop real-time DSP systems. *Prerequisite: EECE 691 or EECE 491 or consent of instructor.*

EECE 693 Neural Networks 3 cr.
The course provides a comprehensive foundation to artificial neural networks and machine learning with applications to pattern recognition and data mining; learning processes: supervised and unsupervised, deterministic and statistical; clustering; single layer and multilayer perceptrons; least-mean-square, back propagation, deep learning; Al-Alaoui pattern recognition algorithms; radial basis function networks; committee machines; principal component analysis; self-organizing maps; current topics of interest.

EECE 694 Digital Image Processing 3 cr.
An introduction to multi-dimensional signal processing; digital image fundamentals; image formation and perception; image representation, coding and filtering; image enhancement in the spatial and frequency domains; image restoration; color image processing; wavelet and multi-resolution processing; image compression; morphological image processing; image segmentation; feature extraction and scene analysis; representation and description; object recognition; introduction to computer graphics and computer vision; current topics of interest.

EECE 694L Image Processing Lab 1 cr.
The EECE 694L graduate lab comprises a set of MATLAB/C++ based lab experiments in different image processing topics covering image pre- and post-processing techniques, image compression, morphological transformations, image restoration and enhancement techniques, color image processing, computer vision basics, and geographical image processing. In addition, students will be exposed to software optimizations for real time image processing using SIMD instructions. *Prerequisite: EECE 694 or EECE 603, or consent of instructor.*

EECE 695 Adaptive Filtering 3 cr.
A course that examines the fundamentals of optimal filtering and estimation, Wiener filters, linear prediction, steepest-descent and stochastic gradient algorithms; frequency-domain adaptive filters; method of least squares, recursive least squares, fast fixed order and order-recursive (lattice) filters; misadjustment, convergence and tracking analyses, stability issues, finite precision effects; connections with Kalman filtering; and nonlinear adaptive filters.

EECE 696 Applied Parallel Programming 3 cr.
This course is an introduction to parallel programming and GPU computing. Topics include GPU as part of the PC architecture; CUDA, CUDA threads and CUDA memory; floating point performance; open CL, MPI and reductions, and their implementation. The course also includes application case studies, current topics and a course case study. *Prerequisite: EECE 321 or consent of instructor.*

EECE 697/ MECH 646 Wheeled Mobile Robotics 3 cr.
A course that provides in-depth coverage of wheeled mobile robots. The material covers: nonholonomy and integrability of kinematic constraints. Modeling: kinematics, dynamics and state-space representation. Nonlinear control strategies (open-loop and closed-loop). Five case studies are covered during the course: car-like, cart-like, omni-directional wheeled, mobile wheeled pendulums and bike-like robots.

EECE 698/ MECH 650 **Autonomous Mobile Robotics** **3 cr.**
This course is designed to provide engineering graduate and 4th year students with the opportunity to learn about autonomous mobile robotics. Topics include sensor modeling, vehicle state estimation, map-based localization, linear and nonlinear control, and simultaneous localization and mapping. *Prerequisites: EECE 230, EECE 312, and MECH 436; or EECE 230 and EECE 460; or consent of instructor.*

EECE 699 **Topics in Artificial Intelligence** **3 cr.**
This course focuses on some selected topics in AI related to agent and multi-agent systems, life-long learning and artificial life. Specifically, this course covers both theoretical and technical issues in reinforcement learning, transfer learning, evolutionary approaches, quantum genetic algorithms and explainable AI. The course also has a practical project for students to explore learned concepts from a contemporary lens.

EECE 731 **Advanced Topics in Complexity Theory** **3 cr.**
The course covers advanced topics in computational complexity theory. Topics include: hierarchy theorems; relativization; non-uniform models of computations: branching programs and circuits, relations and lower bounds; alternation and the polynomial hierarchy; interactive proofs; probabilistically checkable proofs; pseudorandomness: hardness versus randomness paradigm, generators for space bounded computations, special purpose generators. *Prerequisite: EECE 631 or consent of instructor.*

EECE 732 **Pseudorandomness** **3 cr.**
This course covers the basics of the area of pseudorandomness. Topics include: randomized complexity classes; background material from coding theory; computational indistinguishability and pseudorandom generators; hardness versus randomness: Nisan-Wigderson generator, Impagliazzo-Wigderson theorem; simple generators: k-wise independence and small-bias spaces; unconditional generators for constant depth circuits and space-bounded computation; and randomness extractors. *Prerequisite: EECE 631 or consent of instructor.*

Special Courses and Thesis

EECE 700 **Approved Experience for EICT Students** **0 cr.**

EECE 796 **Special Project**
An assigned project of no more than 3 credit hours supervised by a faculty member.

EECE 797 **Seminar** **0 cr.**

EECE 798 **Special Topics 3 cr.**
Every term.

EECE 799 **Thesis** **6 cr.**
Every term. Prerequisite: EECE 799T.

EECE 799T **Comprehensive Exam** **0 cr.**
Every term.

EECE 898 **Advanced Topics in Electrical and Computer Engineering** **3 cr.**

EECE 980 Qualifying Exam Part I: Comprehensive Exam 0 cr.
Every term.

EECE 981 Qualifying Exam Part II: Defense of Thesis Proposal 0 cr.
Every term. Prerequisite: EECE 980.

EECE 982 PhD Thesis 3 cr.
Every term. Taken while total required credit hours have not been completed.

EECE 983 PhD Thesis 6 cr.
Every term. Taken while total required credit hours have not been completed.

EECE 984 PhD Thesis 9 cr.
Every term. Taken while total required credit hours have not been completed.

EECE 985 PhD Thesis 12 cr.
Every term. Taken while total required credit hours have not been completed.

EECE 986 PhD Thesis 0 cr.
Every term. Taken while total required credit hours have not been completed.

EECE 987 PhD Thesis Defense 0 cr.
Every term. Prerequisite: EECE 981.