Electrical Engineering (EENG)

Department of Computer Science and Electrical Engineering

GARY M. CARTER, Chair
GARY M. CARTER, Graduate Program Director

Professors
ADALI, TULAY, Ph.D., North Carolina State University: Statistical signal processing, machine learning for signal processing, adaptive signal processing, biomedical data analysis, and communications

CARTER, GARY M., Ph.D., Massachusetts Institute of Technology: Optical communications, non-linear optics, lasers, bio-photonics

CHANG, CHEIN-I, Ph.D., University of Maryland, College Park: Multispectral/hyper-spectral imaging, chemical/biological defense, automatic target recognition (ATR), computer-aided diagnosis for medical imaging, visual information systems and retrieval

CHEN, YUNG JUI (RAY), Ph.D., University of Pennsylvania: Optical networks, integrated optics and opto-electronic integrated circuits, device physics, ultra-fast optics and non-linear optics

CHOA, FOW-SEN, Ph.D., State University of New York, Buffalo: MOCVD growth, quantum cascade lasers, mid-IR and THz photonic devices, chip-scale integrated sensor systems, RF-photonic and optical switching devices

JOHNSON, ANTHONY, Ph.D., City College of the City University of New York: Director of the Center for Advanced Studies in Photonics Research (CASPR); Ultra-fast optics, non-linear optics and ultra-fast photophysics of nano-structured materials

MENYUK, CURTIS R., Ph.D., University of California, Los Angeles: Optical communications, non-linear optics, theoretical electromagnetics

MORRIS, JOEL M., Ph.D., The Johns Hopkins University: Communication theory and statistical signal processing theory with applications in sensing, detection, estimation, and characterization, error correction codes, adaptive importance sampling for statistical performance assessment, joint time-frequency/time-scale analysis and presentations

YAN, LI, *Professor*, Ph.D., University of Maryland, College Park; Ultra-fast optics, non-linear optics, solid-state and fiber lasers, optical communications

Associate Professor
RUTLEDGE, JANET, Ph.D., Georgia Institute of Technology: Modeling and Compensating for the effects of sensorineural hearing loss and other communication disorders

Professor of Practice
LABERGE, E.F. CHARLES, Ph.D., UMBC: Coding theory, signal processing, communication system design, interface analysis, safety-critical avionics, system engineering

Degrees Offered

M.S. (thesis and non-thesis), Professional M.S., and Ph.D. Check the CSEE Department and ENEE Graduate Program websites www.csee.umbc.edu or www.cs.umbc.edu/programs/graduate/electrical-engineering-ms-phd/, respectively, for current and further details on these degrees, the 5-year B.S./M.S. degree, and program certificates.

Program Description

The CSEE Department offers a graduate program (EENG/ENEE) leading to the Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Electrical Engineering (EE). The diversity of course offerings and research interests within the department, and interactions with the medical and dental schools at the University of Maryland, Baltimore, and other science and engineering departments at UMBC, encompass a broad spectrum of strictly electrical engineering and inter-disciplinary instruction and research topics. The M.S. program has three (3) possible tracks of study: (a) nano/micro/opto-electronics, photonics, and sensor technology (*n*EPS); (b) communications, sensor systems, and signal processing (CSSP); and (c) systems engineering (SE). The Ph.D. program has only the first two (2) tracks of study (*n*EPS and CSSP). The faculty's interests and the various topics defining these tracks of study are:

Communications: random processes, detection and estimation theory, information theory, source and channel coding, communication theory, wired/wireless/optical-fiber communications, data compression, adaptive and machine-learning techniques.

Nano/micro/opto-electronics: solid-state electronics, semiconductor devices and processing technology, semiconductor opto-electronics, compound semiconductor electronics, and integrated circuits.

Photonics: electromagnetic theory, quantum electronics, solid-state and fiber lasers, semiconductor and quantum-cascade lasers, fiber-optic communications, optical networking and interconnections, non-linear/integrated optics/ultra-fast/sub-wavelength optics, and bio/nano/silicon-photonics.

Sensor Technology: bio-chemical and opto-electronic-sensors.

Signal Processing: signal and linear system theory; digital signal processing (DSP); statistical signal processing (detection, estimation, machine-learning); adaptive and learning techniques; speech processing; pattern recognition; spectral, time-frequency, and joint-domain analysis; biomedical signal processing; and sensor-based systems and networks.

Image Processing: automatic target recognition, pattern recognition, image coding and compression, multi-/hyper-spectral imaging, biomedical imaging and image analysis, visual information systems and retrieval.

Systems Engineering: life-cycles of complex systems; system architecture and design; system modeling, simulation, and analysis; system implementation, integration, and test; and systems of systems.

ENEE students, except for those in the SE track, may select their course and research plan in one track of study or in an interdisciplinary area approved by their advisor and the Graduate Program Director. A departmental brochure that describes in more detail the department, its graduate programs, degree requirements, and the research interests of the faculty can be obtained from the graduate program specialist or can be viewed at either the CSEE Department or ENEE Graduate Program websites, www.csee.umbc.edu or www.cs.umbc.edu/programs/graduate/electrical-engineering-ms-phd/, respectively.

Degree Requirements

Master of Science (M.S.) Degree

Within five (5) years of admission, the student must earn a minimum of 30 credit hours for the thesis option or 33 credit hours for the non-thesis (w/project) option. All M.S. students MUST choose either the thesis or non-thesis (w/project) option: there is no course-only option. Students must satisfy the grade and course requirements for their field of specialty and option. Unless approved by the Graduate Program Director (GPD), a maximum of six (6) credits of courses outside the EE program will be accepted. These courses must be at the graduate level and must be approved by the student's advisor and the GPD prior to registration.

Course Requirements
Four-of-eight (4 of 8) *core courses required for all students* (12 credits):

ENEE 601: Linear Systems Theory
ENEE 620: Probability and Random Processes
ENEE 621: Detection and Estimation Theory
ENEE 622: Information Theory

ENEE 630: Solid-State Electronics
ENEE 631: Semiconductor Devices
ENEE 680: Electromagnetic Theory
ENEE 683: Lasers

Two (2) *or four* (4) *EE electives* (6 or 12 credits): 600-level. Check the ENEE Graduate Program website for the current list of approved ENEE 600-level choices for the chosen track. The 2 electives requirement is for the thesis option, and the 4 electives for the non-thesis option.

Two (2) *additional electives* (6 credits): 600/700 level, advisor-approved courses (can include a maximum of 3 credits from ENEE 698/699).

EE Graduate Seminar: M.S. students are required to take EE Graduate Seminar (ENEE 608) for one (1) semester, preferably in the first year.

Transfer Credits: No more than six (6) credits may be transferred from another university or from UMBC as a non-degree student. Course credit transfer must be approved by the Graduate Program Director.

Grade Requirements: Students must receive a 'B' or higher (equivalently, a grade point average (GPA) of 3.0 or better) in each of the four (4) core courses. Grades with + and - are possible for graduate courses. A minimum grade of 'B' (3.0 GPA) is required for courses taken for the degree.

M.S. Thesis Option (30 credits)
A student may undertake the M.S. thesis option, which would be supervised by a faculty member as the research advisor (or co-advisor). The thesis option requires a minimum of eight (8) graduate-level courses (24 credits), as specified above, and six (6) credits of M.S. thesis research (ENEE 799). The thesis research must contain a tangible research component. Upon completion of the thesis, it must be defended with an oral public exam/presentation and accepted with the approval of the student's thesis committee. The committee must consist of at least three (3) graduate faculty members within the department. Copies of the approved thesis must be submitted both to the CSEE Department and the Graduate School.

Non-Thesis Option (33 credits)
A student may undertake the M.S. non-thesis option, which would be supervised by a faculty member as the research advisor (or co-advisor). The non-thesis option requires a minimum of ten (10) graduate-level courses (30 credits), as specified above, and three (3) credits of graduate project research (ENEE 698) resulting in a scholarly paper that must be approved by the advisor and read by another faculty member. A copy of the approved scholarly paper must be submitted to the department.

For the Systems Engineering (SE) track, the four (4) electives (12 credits) must be

ENEE 660: System Engineering Principles
ENEE 661: System Architecture and Design
ENEE 662: System Modeling, Simulation, and Analysis
ENEE 663: System Implementation, Integration, and Test

Doctor of Philosophy (Ph.D.) Degree

Each field of specialty sets its course requirements for doctoral students in that field. The department's minimum requirement is eleven (11) courses (beyond the bachelor's degree). The doctoral student must spend the equivalent of at least three years of full-time residency, with at least one year on the UMBC campus. The doctoral dissertation must be an original and substantive contribution to knowledge in the student's major field. It must demonstrate the

student's ability to carry out a program of research and to report the results in accordance with standards observed in the recognized scientific journals related to that field.

Doctoral students must: (a) submit their PhD Comprehensive Portfolio and receive a pass grade (P) within four (4) semesters of entrance to the program (six (6) semesters for part-time students); (b) develop and defend a doctoral dissertation proposal and be admitted to doctoral candidacy within four (4) years of entrance to the program; and (c) complete all Ph.D. requirements for their field of specialty within four (4) years of admission to doctoral candidacy.

PhD Comprehensive Portfolio
The ENEE PhD Comprehensive Portfolio consists of three (3) components: (a) GPA performance on the four (4) core plus ENEE 610 courses, (b) the Research Activity Report (RAR), and (c) two (2) faculty support letters. Students will be dismissed from the doctoral program if they fail to pass the comprehensive portfolio evaluation within the specified time frame. See the ENEE Graduate Program website at www.csee.umbc.edu or www.cs.umbc.edu/programs/graduate/electrical-engineering-ms-phd/ for details on the ENEE PhD Comprehensive Portfolio policy.

Course Requirements
Students must satisfy the minimum course requirements for their field of specialty (typically 11 courses totaling 33 credits) excluding the EE graduate seminar (ENEE 608), graduate research credits prior to Ph.D. candidacy, and doctoral dissertation research credits. Four (4) of the eleven (11) courses must be chosen from the eight (8) core courses and the fifth (5^{th}) course is Digital Signal Processing (ENEE 610). Students may take ENEE 898 for research credits before being admitted to Ph.D. candidacy and must take eighteen (18) credits of ENEE 899 for doctoral dissertation research after admittance to Ph.D. candidacy. Specifically:

Four-of-eight (4 of 8) *core courses required for all students* (12 credits):

ENEE 601: Linear Systems Theory
ENEE 620: Probability and Random Processes
ENEE 621: Detection and Estimation Theory
ENEE 622: Information Theory
ENEE 630: Solid-State Electronics
ENEE 631: Semiconductor Devices
ENEE 680: Electromagnetic Theory
ENEE 683: Lasers

Required core course: ENEE 610: Digital Signal Processing (3 credits)

Four (4) *EE electives* (12 credits): two (2) or more at 700-level. Check the ENEE Graduate Program website for the current list of approved ENEE 700-level choices for the chosen track.

Three (3) *additional electives* (9 credits): advisor-approved 600/700 level, which can include a maximum of three (3) credits of ENEE 698/699

EE Dissertation Research: ENEE 899 (18 credits, over at least two (2) semesters).

EE Graduate Seminar: Ph.D. students are required to take EE Graduate Seminar (ENEE 608) for two (2) semesters, preferably in the first year.

Grade Requirements
A grade of 'B' (3.0 GPA) or better is required in all courses and a 3.33 GPA minimum overall (including the transfer courses). Grades with + and - are possible for graduate courses.

PhD Comprehensive Portfolio
The ENEE PhD Comprehensive Portfolio consists of three (3) components: (a) GPA performance on the four (4) core plus ENEE 610 courses, (b) the Research Activity Report (RAR), and (c) two (2) faculty support letters. Students will be dismissed from the doctoral program if they fail to pass the comprehensive portfolio evaluation within the specified time frame. See the ENEE Graduate Program website at www.csee.umbc.edu or www.cs.umbc.edu/programs/graduate/electrical-engineering-ms-phd/ for details on the ENEE PhD Comprehensive Portfolio policy.

Preliminary Examination (Prelim)
Students must select a dissertation advisor and a dissertation preliminary examination committee, and they must pass a two-part preliminary examination. Students will present and defend their dissertation proposal to the preliminary committee. The committee examines the students orally on their proposal and research area(s) to assess their ability to complete the proposed research. Each full-time student must pass the preliminary exam within one-and-a-half (1.5) years after passing the comps to remain in the Ph.D. program, and part-time students will be given two-and-a-half (2.5) years to pass the preliminary examination. Check the ENEE Graduate Program website for updates to this requirement.

Ph.D. Candidacy
After passing the preliminary exam and completing the course requirements, the Graduate Program Committee recommends to the Graduate School that the student be admitted to Ph.D. candidacy.

Dissertation Research
The student conducts and reports (dissertation) on a significant original research topic under the guidance of their dissertation advisor. The doctoral dissertation must be an original and substantive contribution to knowledge in the student's major field. It must demonstrate the student's ability to: (a) conduct a program of research and (b) report the results in accordance with standards observed in the recognized scientific journals related to that field. This research must be completed and defended within four (4) years of admission to candidacy. Students must be admitted to candidacy at least two full sequential semesters before the date on which the doctoral degree is to be conferred. Doctoral candidates take at least eighteen (18) dissertation credits (ENEE 899). The Ph.D. dissertation committee must include four (4) graduate faculty members from the CSEE department and one external member.

Residency Requirements
A minimum of three (3) years of full-time graduate study or its equivalent is required. At least one year of full-time study must be completed at UMBC.

Program Admission Requirements

When seeking admission to the graduate program in Electrical Engineering, applicants must satisfy all entrance requirements of the Graduate School at UMBC. These include the submission of official transcripts, three letters of recommendation, statement of purpose, Graduate Record Examination (GRE General Test) scores and, for international students, scores for the TOEFL. All original application materials must be sent directly to the Graduate School, not the graduate program. Application deadlines for international and domestic students are January 1/June 1 for the fall semester, and June 1/November 1 for the spring semester. The application review process will begin by January 1 for admission in the fall semester, and by October 1 for admission in the following spring semester. Early application is recommended.

In addition to the requirements of the graduate school, minimum requirements for admission to the graduate program in Electrical Engineering are a B.S. degree from an ABET-accredited undergraduate program in Electrical Engineering with a GPA equivalent to 'B+' or higher. Individuals whose records indicate strong potential for successful pursuit of the master's or doctoral degree objectives and who have similar undergraduate preparation with strong academic records in computer science, mathematics, physics or other areas of engineering or science are encouraged to apply (B.S. degrees in engineering technology are not considered equivalent to the B.S. degree in engineering or the B.A. degree in the sciences). Students whose degrees are not in electrical engineering generally will be required to take courses to make up deficiencies in their backgrounds. Students who plan to pursue the Ph.D. degree but who do not already have an M.S. degree are advised to apply for admission to the M.S. program. Applicants are judged competitively by the program's admissions committee, and those who appear suitably qualified to complete the requirements of the intended degree program successfully are selected for admission, subject to available resources. Applications are not processed until all documents and fees are received.

Facilities and Special Resources

Faculty and students in the electrical engineering program at UMBC have access to extensive computational resources. The research and instructional activities of the department are supported by a number of new modern

laboratories. Laser-based laboratories support research in ultra-fast non-linear optics and optical spectroscopy, solid state, diode and fiber lasers. Device fabrication laboratories support research in optical and electronic properties of compound semiconductors and organic polymers and in exploring and developing new materials, micro/nano device structures and processing technologies via CAIBE. Compound semiconductor growth research, such as quantum cascade lasers, is being pursued using MOCVD techniques. The optical communication and optical networking laboratories contains high-performance, fiber-optics communication equipment to perform experiments in digital transmission using multi-channels over long distances and optical networking. The communications and signal processing laboratory supports research in the areas of communication theory and statistical signal processing theory with their applications. The remote sensing signal and image processing laboratory supports research in multi-spectral and hyper-spectral imagery, pattern recognition, target tracking and detection, image coding and progressive image transmission, computer vision, and medical imaging. The machine learning laboratory supports research in theory and algorithms in adaptive and/or non-linear signal processing for communications and biomedical image analysis. Collaborations with nearby federal facilities include ARL, LTS, LPS, NASA, NIH, NIST, and NRL, and with the Kennedy Krieger Center at Johns Hopkins University and the Department of Radiology at the University of Maryland Medical School.

Financial Assistance

Financial aid is available on a competitive basis to a limited number of qualified graduate students in the form of graduate teaching assistantships (TAs), graduate research assistantships (RAs), work-study positions, and hourly employment as graders. Graduate RAs are often available to students actively engaged in a master's thesis or doctoral dissertation research, and are awarded and renewed subject to availability of funds and satisfactory research progress. Students are encouraged to apply directly to nationally awarded fellowship programs.

COURSE LISTING

For ENEE (also CMPE and CMSC) course descriptions, and current year special topic course listings and descriptions, see the CSEE Graduate Program(s) website www.cs.umbc.edu/programs/graduate/ or CSEE Department website www.csee.umbc.edu. The set of ENEE 691 courses address specialized electrical engineering topics representing the research focus of the faculty, and are scheduled according to student and faculty interests.

ENEE 601 Signal and Linear Systems Theory [3]
ENEE 608 Graduate Seminar [0]
ENEE 610 Digital Signal Processing [3]
ENEE 611 Adaptive Signal Processing [3]
ENEE 612 Digital Image Processing [3]
ENEE 620 Probability and Random Processes [3]
ENEE 621 Detection and Estimation Theory I [3]
ENEE 622 Information Theory [3]
ENEE 623 Communication Theory I [3]
ENEE 624 Error-Correcting Codes [3]
ENEE 625 Data Compression [3]
ENEE 630 Solid-State Electronics [3]
ENEE 631 Semiconductor Devices [3]
ENEE 632 Integrated Circuits [3]
ENEE 634 Microwave Device and Circuit Design [3]
ENEE 635 Introduction to Optical Communications [3]
ENEE 636 Introduction to Wireless Communications [3]
ENEE 660 Systems Engineering Principles [3]
ENEE 661 System Architecture and Design [3]
ENEE 662 Modeling, Simulation and Analysis [3]
ENEE 663 System Implementation, Integration and Test [3]
ENEE 671 Service Oriented Architecture [3]

ENEE 680 Electromagnetic Theory I [3]
ENEE 683 Lasers [3]
ENEE 684 Introduction to Photonics [3]
ENEE 685/CMPE 485 Introduction to Communication Networks [3]
ENEE 691 Topics in Electrical Engineering [3]
ENEE 698 Research Project in Electrical Engineering [1-3]
ENEE 698 Research Project in Electrical Engineering (Systems Engineering Project) [1-3]
ENEE 699 Independent Study [1-3]
ENEE 710 Digital Speech Processing [3]
ENEE 711 Neural Networks in Signal Processing [3]
ENEE 712 Pattern Recognition [3]
ENEE 718 Advanced Topics in Signal Processing [3]
ENEE 721 Statistical Signal Processing [3]
ENEE 723 Multi-user Communication [3]
ENEE 728 Advanced Topics in Communications [3]
ENEE 737 Semi-conductor Device Processing Techniques [3]
ENEE 738 Characteristics of Semi-conductor Opto-electronics [3]
ENEE 785 Advanced Topics in Optical Networks [3]
ENEE 788 Advanced Topics in Electrophysics and Photonics [3]
ENEE 799 Master's Thesis Research [1-6]
ENEE 898 Pre-Candidacy Doctoral Research [1-6]
ENEE 899 Doctoral Dissertation Research [6]