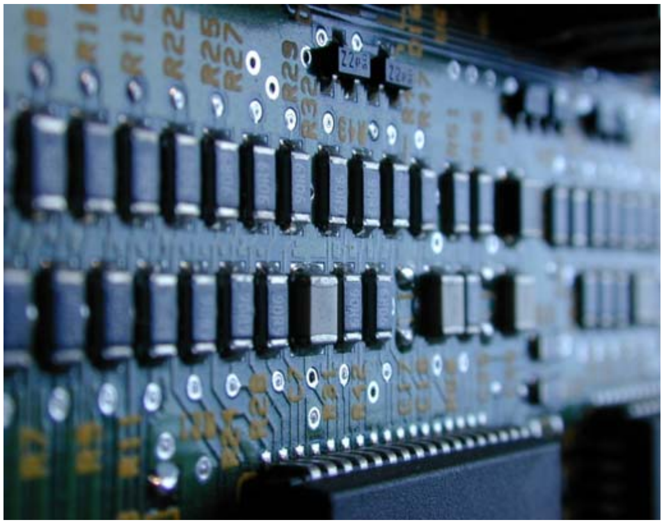
Electrical and Computer Engineering

Student Handbook

2012-2013



Dept. of Electrical and Computer Engineering

University of Massachusetts Lowell
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Academic Schedule- Fall 2012

Sept. 1	Saturday Residence halls open for new students
Sept. 2	Sunday Residence halls open for returning students
Sept 3	Monday Labor Day (University Closed)
Sept. 4	Tuesday Convocation
Sept. 5	Wednesday Fall Classes Begin Add/Drop Period Begins
Sept. 11	Tuesday Last Day for Undergraduate Students to Add A Course without a Permission Number . Last Day for Instructors to Publish Course and Attendance Requirements for Class Members
Sept. 18	Tuesday Last Day to (1) Add a Course with a Permission Number ;(2) Drop a Course without Record, (3) Change Enrollment Status from: Audit to Credit; Credit to Audit; "Pass-No Credit" to Letter Grade, or Letter Grade to "Pass-No Credit" Note: No refund after this date
Oct. 8	Monday Columbus Day (University Closed)
Oct. 16	Tuesday Mid-Semester: At least one evaluation required in each course.
Oct. 29	Monday Faculty Advising Period Begins. Students check ISIS for enrollment appointments First day for seniors who anticipate completion of Degree Requirements by the End of May or the end of August to Confer with Faculty Advisors and to File; Programs of Baccalaureate Studies (DIG Forms)
Nov. 5	Monday Enrollment for Spring 2013 courses begin using enrollment appointment dates obtained from student ISIS self service . Last day for students to complete work for incomplete spring semester and summer (2012) courses
Nov. 12	Monday Veterans Day Observed (University closed)
Nov. 13	Monday Faculty Advising Period Ends Last Day for Seniors Who Anticipate Completion of Degree Requirements by the End of May or the End of August to Confer with Faculty Advisors and to File Programs of Baccalaureate Studies (DIG form)
Nov. 14	Wednesday Last Day for Students to withdraw from courses with grade of "W".
Nov. 21	Wednesday Thanksgiving Recess Begins 6:00pm
Nov. 26	Monday Classes Resume
Dec. 3	Monday Last Day for Faculty to Administer Quizzes and Examinations Prior to Final Examination Period
Dec. 10	Monday Last Day of Fall Semester Classes ;Last Day for Faculty to File Grades for Incompletes and Change of Course Grades for Spring & Summer Semester (2012) courses
Dec. 11	Tuesday Reading Day
Dec. 12	Wednesday Fall Semester Examinations Begin (no Saturday or Sunday Final exams)
Dec. 20	Thursday Fall Semester Examinations End 6:00 P.M. Residence halls close at 6:00 P.M.
Dec. 21	Friday Make-up day for examinations postponed because of Weather. Winter Recess Begins
Dec. 25	Tuesday Christmas

Academic Schedule - Spring 2013

Jan. 20	Sunday Residence halls open at 12 Noon
Jan. 21	Monday Martin Luther King Day (University Closed)
Jan. 22	Tuesday Spring Classes Begin; Drop-Add Period Begins
Jan. 28	Monday Last Day For Undergraduate Students to Add Courses Without a Permission Number Last Day for Instructors to Publish Course and Attendance Requirements for Class Members
Feb. 4	Monday Last Day for Registered Students to (1) Add a Course with a permission number ;(2) Drop a Course Without Record, and (3) Change Enrollment Status from: Audit to Credit, Credit to Audit, "Pass-No Credit" to letter grade; or Letter grade to "Pass No-Credit". Note: No Refunds after this date
Feb. 18	Monday Presidents Day (University Closed)
Feb. 19	Monday class schedule
Mar. 8	Friday Mid-Semester: At Least One Evaluation Required in Each Course.
Mar 11	Monday Spring Recess
Mar. 17	Sunday Residence halls open at 12 noon
Mar. 18	Monday Classes Resume
Apr 3	Wednesday Last Day for student sto complete work for incomplete Fall 2012 courses
Apr. 8	Monday Faculty Advising Period for Fall Semester (2013) Begins. First Day for Seniors Who Anticipate Completion of Degree ;Requirements by the End of December (2012) to Confer with Faculty Advisors and to File Programs of Baccalaureate Studies (DIG Forms)
Apr. 10	Wednesday Last Day for Students to withdraw from courses with grade of "W".
Apr. 15	Monday Patriot's Day (University Closed)
Apr. 16	Tuesday Student Registration Begins for Fall 2013 Semester courses via ISIS student self service based on enrollment appointments.
Apr 17	Wednesday Monday class Schedule
Apr. 22	Friday Faculty Advising Period for Fall Semester (2013) Ends ;Last Day for Seniors Who Anticipate Completion of Degree Requirements by the End of December (2013) to Confer with Faculty Advisors and to File Programs of Baccalaureate Studies
Apr. 24	Wednesday Last Day for Faculty to Administer quizzes and examinations prior to Final examination period
Apr 26	Friday University Day (Classes Meet)
May 1	Wednesday Last Day of Spring Semester Classes ;Last Day for Faculty to File Grades for Incompletes, and Changes of Course Grades for Fall & Intersession Semester (2012) Courses
May 2	Tuesday Reading Day
May 3	Friday Spring Semester Examinations Begin (There will be no final exams on Saturdays.)
May 13	Monday Spring Semester examinations end 6:00 P.M. Residence halls close 6:00 P.M.
May 14	Tuesday Make-up day for examinations postponed because of weather.
May 18	Saturday University Commencement

Welcome

Welcome to the Electrical and Computer Engineering (ECE) Department at the University of Massachusetts Lowell. This handbook is a resource for both current and prospective students. Our department offers a diverse curriculum at both the undergraduate and graduate levels. Bachelor and Master degrees in engineering are offered in both Electrical Engineering and Computer Engineering. Our graduate program also offers a doctorate in engineering in Electrical Engineering and Computer Engineering. Our team of experienced faculty has active research programs in a variety of specialization areas including telecommunications, microwave technology, optoelectronic devices, digital signal processing, wireless communications, power distribution, alternative energy sources, nanotechnology, embedded computing, and networking. Our facilities include numerous laboratories and five research centers that span diverse areas of electrical and computer engineering, enabling research at both the graduate and undergraduate level.

Please feel free to contact us with any questions about our program.

Professor Martin Margala, ECE Department Chair

Table of Contents

Department Administration

Department Chair	Martin Margala, Ext. 2986
Associate Chair	George Cheney, Ext. 3331
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Graduate Coordinator	Anh Tran, Ext. 3322
Undergraduate Committee Chairman	Jay Weitzen, Ext. 3315
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*starting August 1, 2012

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Electrical and Computer Engineering at UMass Lowell

Electrical and Computer Engineering are dynamic fields, advancing as a result of breakthroughs in technology as well in the pure sciences. Because engineering disciplines continuously incorporate new concepts and developments, a viable engineering education cannot be limited to the acquisition of specific skills and methods, but must also provide the student with a deep understanding of both the current and the emerging engineering fields.

The ECE Department is well placed to help fulfill the campus' role within the University of Massachusetts system. The faculty embraces the mission of serving a technologically oriented Department, closely linked to regional and national industry.

Mission Statements

University: The University of Massachusetts Lowell is a comprehensive, public institution committed to excellence in teaching, research and community engagement. We strive to transform students to succeed in college, as lifelong learners and as informed citizens in a global environment. UMass Lowell offers affordable, experience-based undergraduate and graduate academic programs taught by internationally recognized faculty who conduct research to expand the horizons of knowledge. The programs span and interconnect the disciplines of business, education, engineering, fine arts, health and environment, humanities, sciences and social sciences. The University continues to build on its founding tradition of innovation, entrepreneurship and partnerships with industry and the community to address challenges facing the region and the world.
(also published at http://www.uml.edu/About/default.aspx)

College of Engineering: The Francis College of Engineering seeks to prepare men and women to be successful in engineering or their chosen profession. The faculty and staff of the Francis College of Engineering are strongly committed to providing our students with a high quality education relevant to the needs of society and industry. We will do this in a cooperative atmosphere that facilitates learning and cares about the needs of our students. (also published at http://www.uml.edu/catalog/undergraduate/colleges/engineering/objectives/objectives.htm)

ECE Department: The ECE Department mission for undergraduate education is to provide a thorough grounding in electrical science, electrical engineering, and computer engineering, together with an intensive training in mathematics. The techniques of experimental science and technology are emphasized through investigative laboratory work and classroom lecture/demonstrations.

The curriculum includes engineering science and design courses that provide a balanced view of hardware, software, application trade-offs and the basic modeling techniques and the use of computer aided design tools. Such experiences are integrated throughout the curriculum and are designed to encourage each student to engage in a major and meaningful design experience. An important aspect of the ECE curricula is the technical elective program of the senior year. Technical electives provide opportunities for both broadening and deepening technical knowledge according to student interests and competencies. Double majors in Computer Science and Physics are also offered. The capstone project is organized to bring together knowledge from several courses to solve a real-world engineering problem. The ECE Department also cooperates with many local companies, both large and small, in order to offer co-op opportunities for which course credit can be earned.

The ECE Department has long been known throughout the region for producing competent "hands-on" engineers who are the mainstay of the region's industries. For example, Raytheon, a major employer in the region, has more University of Massachusetts Lowell EE and CpE graduates than from any other Department in the country. We value this reputation and, in concert with industry's needs but without compromising the long term value of the educational needs, we strive to maintain and enhance this image. The ECE Department offers a co-op program which the College of Engineering and the University have helped to formalize. We believe that making such opportunities available to students greatly enhances their experience of engineering both with respect to the relevance of our courses as well as the exposure to working with other professionals.

The ECE Department has also developed a project-based Capstone program for seniors that is designed to provide support to the disabled. Many electronic and microprocessor based systems have been delivered that have made a major impact on the freedom and quality of life for the disabled.

A portion of the curriculum for ECE students is also devoted to studies in the humanities and social sciences and a wide choice of subjects is allowed. These General Education (GenEd) courses serve to broaden the student's outlook and focus attention on the importance of non-technical knowledge in determining the student's ultimate level of responsibility in professional life.

Local industry is our main constituency. Most of our students enter industry and a significant percentage find positions at companies within 100 miles of Lowell. While some go to graduate school directly, our typical graduates go directly into the workforce with the expectation that the employer will fund their graduate school education. Since the majority of our graduate student body is part time, our graduate courses are offered in the evenings, enabling students to take one or two courses per semester.

The ECE Industry Advisory Board plays an important role in considering our program objectives by providing us immediate industrial needs. Input from our advisory board serves to continually assess the relevancy of the curriculum to the needs of industry. These needs must be balanced against the need to deliver fundamental knowledge that will enable our graduates to evolve with the latest technological advances. Technical areas sometimes take second place to a "can-do" attitude, excellent communication skills, and the initiative required to teach oneself. Meetings with our Industry Advisory Board occur once per semester. Our close ties with industry through the co-op program, research and consulting, and alumni interactions provide valuable feedback on our program with respect to the skill sets required to function in a working environment.

Strategic alliances have been formed with several of our Industry Advisory Board members. For example, Analog Devices has funded a scholarship program that provides four undergraduate ECE students a guaranteed internship during the winter and summer vacations. A pipeline of co-op students is in place with several companies, providing for very close interaction and feedback between our programs and their expectations. Ten other companies have since joined the Scholar-Intern program, offering scholarships to prospective ECE students.

Our graduate programs leverage the strengths of the department faculty and complements the undergraduate program. Our faculty have close ties with local and regional industry through consulting and research. Our professors also advise graduate students from regional companies, and participate in local and national professional societies and organizations.

Research Centers and Laboratories

The ECE Department is both nationally and internationally recognized for its research in several areas, such as alternative power sources, electromagnetic scattering, electromagnetic materials, photonics, acoustics, signal processing, networking, and imaging.

The ECE Department maintains several Research Centers including:

- Advanced Electronics Technology Center
- Center for Advanced Computation and Telecommunications
- Center Computer Man/Machine Intelligence, Networking & Distributed Systems
- Center for Electric Cars and Energy Conversion
- Center for Electromagnetic Materials and Optical Systems

Research is also supported by many laboratories including:

- Advanced Digital Systems Design and Microprocessors Laboratory
- Battery Evaluation Laboratory
- Computer Architecture and Network Systems Laboratory
- Distributed Integrated Semiconductor Processing Laboratory
- Electric Vehicle Laboratory
- Electromagnetic and Complex Media Laboratory
- Microwave Anechoic Chamber Facility
- Networking, Artificial and Machine Intelligence and Computer Vision Laboratory
- Renewable Energy Laboratory
- Raytheon Microwave Laboratory
- Converged Networking Laboratory

Instructional Laboratories

The department maintains several laboratories that are oriented at instructional activities. Many of these labs have been established with the support of local companies. These labs include:

- Raytheon Microwave Laboratory
- VLSI Design Laboratory
- Analog Devices Analog Electronics Laboratory
- EST/Wind River Laboratory for embedded microprocessor programming
- Capstone Project Laboratory, for assistive technology projects
- Sophomore Circuits Laboratory
- Junior Electronics Laboratory
- Virtual Instrumentation Laboratory

Undergraduate Programs

The ECE Department offers two undergraduate degrees, a B.S. Eng. in Electrical Engineering and a B.S. Eng. in Computer Engineering. The ECE Department also offers opportunities for double majors with Computer Science (CS) and Physics. Detailed programs of study for these double majors are described later in this handbook.

All undergraduate students are assigned faculty advisors and students are required to meet with their advisors, during registration periods or anytime there is some matter of concern. Students should consult with their advisor on the best path through their chosen track. This is especially true for co-op and part-time students, since the need to adhere to prerequisite course requirements is very important. The programs of study for each degree are described below.

Focus Areas

The ECE Department has five technology focus areas :

- Computer Engineering
- Electrical Power and Energy Engineering
- Electromagnetic and Electromagnetic Properties of Materials
- Micro- and Optoelectronic Materials, Circuits and Systems
- Telecommunications and Information Engineering

Program Objectives

Specific program objectives in support of our undergraduate educational mission are that after 4-5 years of experience, our graduates should:

1. Be established and recognized as a valued professional and effective communicator in industries related to electrical, computer and electronic technologies.

2. Practice their profession in a collaborative, team-oriented manner that embraces the multidisciplinary and multicultural environment of today's business world.

3. Engage in lifelong learning and professional development via post graduate education and participation in professional organizations.

4. Function as a responsible member of society with willingness to mentor fellow employees and an understanding of the ethical, social and economic impact of their work in a global context.

Program Outcomes and Assessment

Given our student body and our particular constituencies, our program outcomes can be summarized as follows:

When a UML ECE student graduates he/she shall have:

1. A strong grounding in the fundamentals including the ability to formulate and solve engineering problems by applying the principles of mathematics, science and electrical & computer engineering.

2. Ability to analyze and synthesize engineering problems including design and conduct experiments, use standard test equipment and interpret experimental data.

3. Ability to design reliable systems, devices or processes from initial specifications to a deliverable system.

4. Ability to work in a multidisciplinary team environment.

5. Ability to communicate effectively in both verbal and written forms.

6. Ability to appreciate the complexities of professional environments, including taking responsibility for oneself, working effectively and professionally as a team member, and being mindful of ethical, economic, and contemporary concerns.

7. Competence in taking the initiative for one's own professional development and recognition of the need and ability in engaging in post graduate education and lifelong continual learning.

8. Ability to independently accomplish engineering tasks

9. Ability to enter industry with the engineering techniques, skills, and tools required to be able to solve real-world problems in electrical and computer engineering.

General Education Requirements

Students are required to take three Social Science courses and two Art and Humanities chosen from the list in the schedule book. General Education courses are identified in the "Gen. Ed" column in the curriculum plans with appropriate designations. Courses must have a complete course number listed in the University Course Schedule Book to be accepted. Further information regarding General Education courses can be found in the University Course Schedule Book and at http://www.uml.edu/gened.

B.S.E. in Electrical Engineering (EE)

The B.S.E. in EE track provides a thorough grounding in the fundamentals of electrical engineering that would allow a graduate to function effectively in industry or continue on to graduate school. A typical curriculum is:

Freshman Year / Fall Semester		Cr.
16.100	Intro to ECE I	1
25.107	Intro to Eng. I	2
42.101	College Writing I	3
92.131	***Calculus I	4
95.141	Physics I	3
96.141	Physics Lab I	1
______		
		14 CH

Freshman Year / Spring Semester		Cr.
25.108	Intro to Eng II	2
42.102	College Writing II	3
92.132	***Calculus II	4
95.144	Physics II	3
96.144	Physics Lab II	1
84.121	Chemistry I	3
84.123	Chemistry Lab I	1
49.201	Economics I	3
		16 CH

Sophomore Year / Fall Semester		Cr.
16.201	Circuit Theory I **	3
16.207	Basic Circuits Lab I	2
16.216	ECE Applications Programming	3
92.231	Calculus III	4
______	General Education Course	3
		15 CH

Sophomore Year / Spring Semester		Cr.
16.202	Circuit Theory II	3
16.208	Basic Circuit Lab II	2
16.265	Logic Design	3
92.236	Eng. Differential Equations	3
49.20x	Economics 1 or II	3
______	Social Science	3
		17 CH

Junior Year / Fall Semester		Cr.
16.311	Electronics I Lab	2
16.333	Electronic Materials Chemistry	3
16.362	Signals & Systems	3
16.364	Eng. Math	3
16.365	Electronics I	3
45.334	Engineering Values	3
		17 CH

Junior Year / Spring Semester		Cr.
16.312	Electronics II Lab	2
16.317	Microprocessors Systems Design I	3
16.360	Eng. Electromagnetics I	3
16.363	*Intro to Probability & Random Processes	3
16.366	Electronics II	3
		14 CH

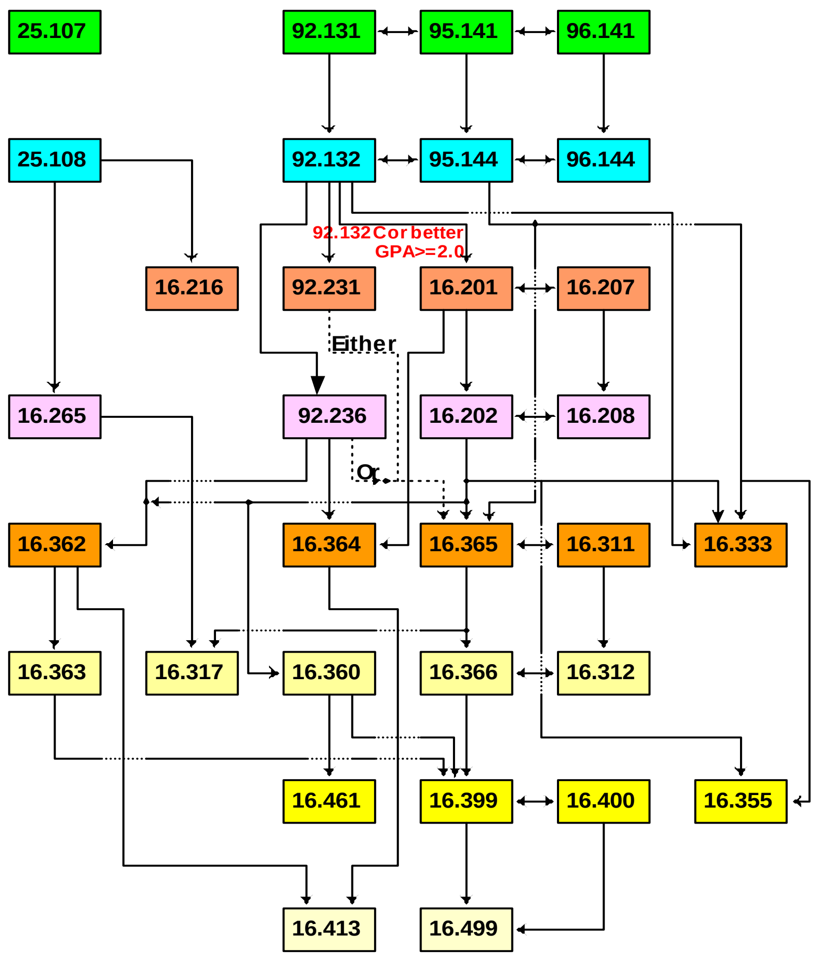
Senior Year / Fall Semester		Cr.
16.355	Electromechanics	3
16.399	Capstone Prop.	3
16.400	Engineering Topics	1
16.461	Eng. Electromagnetics II	3
16.___	****Technical Elective	3
16.___	Arts & Humanities	3
		16 CH

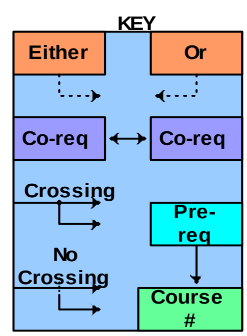
Senior Year / Spring Semester		Cr.
16.413	Lin Feedbk Sys/Discr Sys	3
16.499	Capstone	3
16.____	****Technical Elective	3
______	Social Science	3
		12 CH

Total Degree Credits = 121

* Formerly Signals and Systems II
** A grade of C or better in Calculus II is required
***or 92.128 Calculus 1A AND 92.129 Calculus 1B followed by 92.132 Calculus II
**** Technical electives are non-required courses numbered 16.4xx or 16.5xx

The following Flow Chart shows the sequence of courses taken and the prerequisites for each course in the undergraduate BSE in EE curriculum





A cumulative GPA of 2.0 and a grade of C or better is required to register for 16.201

Original Flow Chart by M. Fiddy
Redrawn and Updated by
A. J. Elbirt, & G. Cheney

B.S.E. in Computer Engineering (CpE)

The B.S.E. in CpE track provides a thorough grounding in the fundamentals of electrical engineering that would allow a graduate to function effectively in industry or continue on to graduate school. A typical curriculum is:

Freshman Year / Fall Semester		Cr.
16.100	Intro to ECE I	1
25.107	Intro to Eng. I	2
42.101	College Writing I	3
92.131	***Calculus I	4
95.141	Physics I	3
96.141	Physics Lab I	1
		14 CH

Freshman Year / Spring Semester		Cr.
25.108	Intro to Eng II	2
42.102	College Writing II	3
92.132	***Calculus II	4
95.144	Physics II	3
96.144	Physics Lab II	1
84.121	Chemistry I	3
84.123	Chemistry Lab I	1
		17 CH

Sophomore Year / Fall Semester		Cr.
16.201	Circuit Theory I **	3
16.207	Basic Circuits Lab I	2
16.265	Logic Design	3
92.231	Calculus III	4
______	Arts & Humanities	3
		15 CH

Sophomore Year / Spring Semester		Cr.
16.202	Circuit Theory II	3
16.208	Basic Circuit Lab II	2
16.216	ECE Applications Programming	3
92.236	Eng. Differential Equations	3
92.360	Math Str. For CpE	3
49.20x	Economics I or II	3
		17 CH

Junior Year / Fall Semester		Cr.
16.311	Electronics I Lab	2
16.322	Data Structures	3
16.362	Signals & Systems	3
16.364	Eng. Math	3
16.365	Electronics I	3
______	General Education Course	3
		17 CH

Junior Year / Spring Semester		Cr.
16.312	Electronics II Lab	2
16.317	Microprocessors Systems Design I	3
16.363	*Intro to Prob. & Random Proc.	3
16.366	Electronics II	3
45.334	Eng. Values	3
______	General Education Course	3
		17 CH

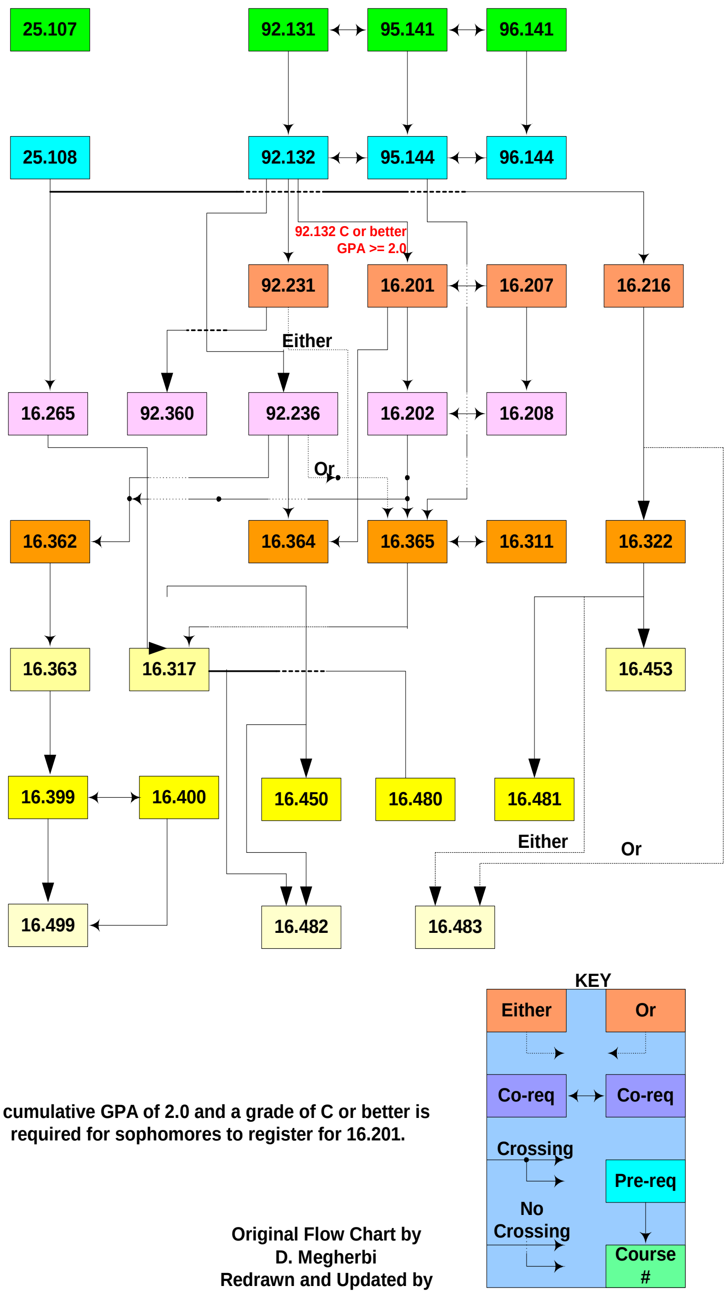
Senior Year / Fall Semester		Cr.
16.399	Capstone Prop.	3
16.400	Engineering Topics	1
16.450	Adv. Dig Sys. Design	3
16.480	Microprocessors II	3
16.481	Operating Sys. & Kernel Design	3
16.___	****Technical Elective	3
		16 CH

Senior Year / Spring Semester		Cr.
16.482	Comp. Arch. & Design	3
16.483	Network Design	3
16.499	Capstone	3
16.____	Arts & Humanities	3
		12CH

Total Degree = 124 CH

* Formerly Signals and Systems II
** A grade of C or better in Calculus II is required
***or 92.128 Calculus 1A AND 92.129 Calculus 1B followed by 92.132 Calculus II
**** Technical electives are non-required courses numbered 16.4xx or 16.5xx

The following Flow Chart shows the sequence of courses taken and the prerequisites for each course in the undergraduate BSE Eng in CpE curriculum



A cumulative GPA of 2.0 and a grade of C or better is required for sophomores to register for 16.201.

Original Flow Chart by D. Megherbi
Redrawn and Updated by G. Cheney

Double Major:Undergraduate EE/CS Curriculum

The ECE Department also offers a double major in Electrical Engineering/Computer Science Students must adhere to the University and college policy on double majors. All curriculum requirements in Engineering must be satisfied. The student must inform both Departments/Colleges by the start of the junior year; the student must submit a program for approval by the Departments involved; the Dean must approve declaration of a double major; a declaration of second major form must be submitted to the Office of Enrollment; students may not present less than 57 credits outside the two major fields in order to satisfy the minimum degree requirements of 120; students are awarded their degree in one college (they must choose one; otherwise, the degree will come from the college originally enrolled in).

Freshman Year/Fall Semester		Cr.
16.100	Intro to ECE	1
25.107	Intro to Eng. I	2
42.101	College Writing I	3
91.101	Computing I	4
92.131	***Calculus I	4
49.20X	Economics I or II	3
		17 CH

Freshman Year/Spring Semester		Cr.
25.108	Intro to Eng II	2
42.102	College Writing II	3
91.102	Computing II	4
92.132	***Calculus II	4
84.121	Chemistry I	3
84.123	Chemistry I Lab	1
		17 CH

Sophomore Year/Fall Semester		Cr.
16.201	Circuit Theory I **	3
16.207	Basic EE Lab I	2
91.201	Computing III	4
92.231	Calculus III	4
95.141	Physics I	3
96.141	Physics Lab I	1
		17CH

Sophomore Year/Spring Semester		Cr.
16.202	Circuit Theory II	3
16.208	Basic EE Lab II	2
92.236	Eng. Differential Equations	3
92.360	Math Structure for CpE	3
95.144	Physics II	3
95.144	Physics II Lab	1
______	Arts & Humanities	3
		18 CH

Junior Year/Fall Semester		Cr.
16.265	Logic Design I	3
16.311	Electronics I Lab	2
16.362	Signals & Systems	3
16.365	Electronics I	3
91.204	Computing IV	3
91.304	Found Computer Sci	3
		17 CH

Junior Year/Spring Semester		Cr.
16.312	Electronics II Lab	2
16.317	Microprocessors Systems Design I	3
16.363	*Intro to Prob & Random Processes *OR*	3
92.386	Stats for Sci & Eng	
16.366	Electronics II	3
91.305	Computer Architecture	3
_____	Arts & Humanities	3
		17 CH

Senior Year/Fall Semester		Cr.
16.333	Electronic Materials Chemistry	3
16.360	Electromagnetics I	3
16.399	Capstone Prop & Comm Skills	3
16.400	Engineering Topics	1
45.334	Engineering Values	3
91.308	Operating Systems	3
91.___	CS Elective (Proj. Req 2 Sem)	3
		19 CH

Senior Year/Spring Semester		Cr.
16.499	Capstone Project	3
91.301	Programming Languages	3
91.404	Analysis of Algorithms	3
91.___	CS Elective (Proj. Cont.)	3
______	Social Sciences	3
______	Social Sciences	3
		18 CH

Total Degree = 140 CH

* Formerly Signals & Systems II
** A grade of C or better in Calculus II is required
***or 92.128 Calculus 1A AND 92.129 Calculus 1B followed by 92.132 Calculus II

Double Major:Undergraduate EE/Physics Curriculum

The ECE Department also offers a double major in Electrical Engineering/Physics. Students must adhere to the University and college policy on double majors. All curriculum requirements in Engineering must be satisfied. The student must inform both Departments/Colleges by the start of the junior year; the student must submit a program for approval by the Departments involved; the Dean must approve declaration of a double major; a declaration of second major form must be submitted to the Office of Enrollment; students may not present less than 57 credits outside the two major fields in order to satisfy the minimum degree requirements of 120; students are awarded their degree in one college (they must choose one; otherwise, the degree will come from the college originally enrolled in).

Freshman Year/Fall Semester		Cr.
16.100	Intro to EE I	1
25.107	Intro to Eng. I	2
42.101	College Writing I	3
84.121	Chemistry I	3
84.123	Chemistry I Lab	1
92.131	***Calculus I	4
95.141	Physics I	3
96.141	Physics I Lab	1
		18 CH

Freshman Year/Spring Semester		Cr.
95.112	Freshman Physics Seminar	1
25.108	Intro to Eng II	2
42.102	College Writing II	3
84.122	Chemistry II	3
84.124	Chemistry II Lab	1
92.132	***Calculus II	4
95.144	Physics II	3
96.144	Physics II Lab	1
		18 CH

Sophomore Year/Fall Semester		Cr.
16.201	Circuit Theory I**	3
16.207	Basic EE Lab I	2
92.231	Calculus III	4
95.269	Physics III (H)	4
96.261	Physics Mat & Dev	3
		16 CH

Sophomore Year/Spring Semester		Cr.
16.202	Circuit Theory II	3
16.208	Basic EE Lab II	2
16.265	Logic Design	3
92.236	Eng. Differential Equations	3
95.210	Intro to Modern Physics	3
96.262	Princ Lab Auto	3
		17 CH

Junior Year/Fall Semester		Cr.
16.311	Electronics I Lab	2
16.362	Signals & Systems	3
16.365	Electronics I	3
92.381	Math Physics I	3
96.393	Adv. Exper Phys I	2
49.20X	Economics I or II	3
		16 CH

Junior Year/Spring Semester		Cr.
16.312	Electronics II Lab	2
16.317	Microprocessors Systems Design I	3
16.363	*Intro to Prob & Random Processes	3
16.366	Electronics II	3
95.382	Math Phys II	3
95.435	Intro Quant Mech I	3
96.394	Adv. Physics Lab II	2
		19 CH

Senior Year/Fall Semester		Cr.
16.360	Eng. Electromagnetics *OR*	3
95.353	Electromagnetism I	3
16.399	Capstone Proposal	3
16.400	Engineering Topics	1
45.334	Eng & Ethics	3
95.421	Stat Therm	3
95.413	Mechanics	3
		16 CH

Senior Year/Spring Semester		Cr.
16.499	Capstone Project	3
_____	General Education (SS)	3
_____	General Education (SS)	3
_____	General Education (AH)	3
_____	General Education (AH)	3
		15 CH

Total Degree = 135 CH

*Formerly Signals & Systems II
** A grade of C or better in Calculus II is required
***or 92.128 Calculus 1A AND 92.129 Calculus 1B followed by 92.132 Calculus II

Combined BSE / MSE Engineering Program

The combined BSE/MSE program is an accelerated program offered by the Department of Electrical and Computer Engineering to encourage its outstanding undergraduate students to continue study at the graduate level. Undergraduate students who have a GPA of 3.00 or better at the end of their junior year and are interested in this program must apply for this program before they complete the undergraduate graduation requirements. Students who apply for the BSE/MSE program are not required to submit the Graduate Record Examination (GRE) scores and are exempted from the application fee

A principal benefit of the early identification of academic goals by the student and advisor is a careful structuring of course work that permits the scheduling of pre-requisites and required courses in sequence, thus affecting a considerable savings of time.

Graduate Programs

The Department of Electrical and Computer Engineering graduate program provides an education based on excellent teaching and cutting-edge research to qualify students as leaders in both industrial and academic environments. It is distinguished by an extensive set of courses in all of the major disciplines within electrical and computer engineering fields. Our mission is supported by six research centers, over ten research laboratories and a world-class faculty with ongoing research in a broad set of disciplines. The program offers masters degrees in both Electrical Engineering and Computer Engineering, as well as two doctoral degrees, Doctor of Philosophy and Doctor of Engineering, in Electrical Engineering and Computer Engineering.

The Department of Electrical and Computer Engineering awards the following graduate degrees:

- Masters of Science in Electrical Engineering
- Masters of Science in Computer Engineering
- Doctor of Philosophy in Electrical Engineering
- Doctor of Philosophy in Computer Engineering
- Doctor of Engineering in Electrical Engineering
- Doctor of Engineering in Computer Engineering

Research is conducted and courses offered in the following areas:

- Artificial/Machine Intelligence
- Bio-Engineering/Bio-Informatics/Bio-Sensors
- Computational Engineering
- Computing and Embedded Systems Hardware and Architecture
- Electric Vehicles and Battery Technology
- Electromagnetics
- Ionospheric Measurements
- Microwave Engineering
- Optoelectronic and Semiconductor Devices
- Power Systems
- Quantum/Nano Electronics
- Signal/Image Processing and Computer Vision
- Solar Energy and Photovoltaics
- Stochastic Processes
- VLSI Design and Fabrication

Four graduate certificates in Electrical and Computer Engineering and six interdisciplinary certificates in corporation with other departments are also offered. These certificates allow students who are not in a degree program to further their education. Approvals to take courses associated with these certificates are subject to approval of the certificate coordinator. Because there is no transfer policy for certificates, students should not take any course for certificates before being accepted.

Electrical and Computer Engineering

- Communications Engineering
- Microwave and Wireless Engineering
- Stochastic Systems
- VLSI and microelectronics

Interdisciplinary

- Biomedical Engineering
- Energy Conversion
- Integrated Engineering Systems
- Nanotechnology
- Photonics and Optoelectronics
- Telecommunications

Master of Science in Engineering (MSE) Programs

The ECE Department offers two Masters programs:

MS Eng. Program in Electrical Engineering (EE)

MS Eng. Program in Computer Engineering (CP)

Graduate Admissions Requirements

General requirement for all applications

All applicants must submit the application materials supplied by the Graduate School as well as the official score report for the Graduate Record Examination (GRE) Aptitude Test.

Students with a BS in Engineering and related areas

Applicants to the MS Engineering in EE or CP programs should hold a BS degree in EE, CP, areas related to EE or CP, Computer Science, Mathematics, Physics, or other Engineering disciplines, with acceptable quality of undergraduate work from an accredited college or university.

Applicants to the MS Engineering in EE or CP should possess the following backgrounds and their pre-requisites.

Electrical Engineering

16.265 Logic Design I
16.311 Electronics Lab I
16.317 Microprocessor Systems Design I
16.360 Engineering Electromagnetics I
16.362 Signal and Systems I
16.365 Electronics I
16.413 Linear Feedback Systems

Computer Engineering

16.216 A high-level programming language such as C/C++
16.265 Logic Design I
16.311 Electronics Lab I
16.317 Microprocessor Systems Design I
16.362 Signal and Systems I
16.364 Engineering Mathematics
(or another appropriate advanced course beyond 92.231 Calculus III and 92.236 Engineering Differential Equations)
16.365 Electronics I

Applicants who lack any of the above backgrounds and their pre-requisites are required to make up their deficiencies as conditions for acceptance.

Students with a BS in Technology

Students who lack the BS Engineering in EE or CP but hold a bachelor's degree in Electrical or Computer Engineering Technology, or Electronics Technology may be admitted under special circumstances. These circumstances include an academic record of high achievement in their undergraduate studies in Technology as evaluated at the discretion of the Graduate Coordinator.

In addition, such students must complete a series of analytically oriented courses in the Department of Electrical and Computer Engineering, University of Massachusetts Lowell.

Students applying for the combined BS/MS program

The combined BS/MS program is an accelerated program offered by the Department of Electrical and Computer Engineering to encourage its outstanding undergraduate students to continue study at graduate level. Undergraduate students who have a GPA of 3.00 or better at the end of their junior year and are interested in this program must apply for this program before they complete the undergraduate graduation requirements. Students who apply for the BS/MS program are not required to submit the Graduate Record Examination (GRE) scores and are exempted from the application fee.

Academic Advisor

The ECE Graduate Coordinator will be the academic advisor to all graduate students admitted to Department. The coordinator will assist in the selection of courses and will work with the student to help meet the degree requirements. In cases where the graduate student pursues a thesis-based program, the students' thesis advisor can also provide guidance on course selection. The Graduate Coordinator is responsible for insuring that Masters students have fulfilled all program requirements prior to graduation. Similarly, the ECE Doctoral Coordinator will coordinate the degree requirements for doctoral students.

Academic Requirements

Graduate students can choose to complete a thesis or a non-thesis option. Students are required to take 9 credits of core courses as well as elective courses to complete their program of study.

1. Credit Requirements

Non-Thesis Option

Core Requirements	9
Technical Electives	21
Advanced Project	3
Total credit hours	33 credits

Thesis Option

Core Requirements	9
Technical Electives	15
Thesis	6
Total credit hours	30 credits

Students in the combined BS/MS program may use up to six credits of graduate courses for both graduate and undergraduate degrees.

Technical electives are Electrical and Computer Engineering graduate course and concentration courses. Students may choose their technical electives in their area of concentration and across other areas to establish a broad knowledge base. Graduate courses in Computer Science, Mathematics, Physics, and other engineering disciplines may be taken as technical electives only if they are pre-approved by the Graduate Coordinator for non-thesis option, or concurrently by the Graduate Coordinator and the student's thesis advisor for thesis option.

The Advanced Graduate Project can be replaced with a 3-credit technical elective.

2. Core Requirements

The objective of the core requirement is to guarantee broad analytical strength for the MS Engineering students.

Required Core Courses for MS in Electrical Engineering

16.507 Electromagnetic Waves and Materials
16.508 Quantum Electronics for Engineers
16.509 Linear Systems Analysis
16.513 Control Systems
16.515 Power Electronics
16.520 Computer-Aided Engineering Analysis
16.543 Introduction to Communications Theory
16.584 Probability and Random Processes
16.595 Solid State Electronics

Students in Electrical Engineering must take three of the above courses that may be pertinent to their area of concentration.

Required Core Courses for MS in Computer Engineering

16.561 Computer Architecture and Design
16.562 VHDL/Verilog Synthesis and Design
(Previous course number 16.602)
16.573 Operating Systems and Kernel Design

3. Concentration

A concentration is generally defined by a coordinated and approved sequence of at least four graduate courses. Each student can choose to work out a concentration either with the graduate coordinator or with his/her academic advisor. Completion of a specific concentration is *not* required for graduation. The course sequences in the concentrations serve as a starting point for establishing a program of study in consultation with the Graduate Coordinator or the student's academic/thesis advisor to meet his/her educational objectives. It is expected that the courses comprising the concentration will complement the work the student will undertake in fulfillment of the research requirement. A list of concentration areas and associated courses are shown below

4. Research Requirement

The research requirement may be fulfilled by completion of an MS Thesis, including registration for six credits of 16.743/16.746 – MS Thesis Research, oral defense of the thesis and submission of the written document. Alternatively, the student may complete an MS Project, including registration for the course 16.733 – Advanced Graduate Project and submission of a written document. If the student chooses not to pursue the MS project, he or she may instead elect to complete a three-credit ECE technical elective. Note that the credits of 16.733 (no more than 3.0) can only be applied toward an MS degree with non-thesis option.

Areas of Concentration

Concentrations are sets of courses address specific topics in EE and CP. Students can choose to select a concentration that reflects their technical interests in preparation for working with a selected industry. As stated earlier, students are <u>not</u> required to choose a concentration.

Concentration courses in Electrical Engineering

Telecommunications

16.510 Digital Signal Processing
16.511 Medical Imaging Diagnosis
16.546 Computer Telecommunications
16.548 Coding and Information Theory
16.582 Wireless Communications
16.586 Stochastic Modeling in Telecommunications
16.617 Modeling and Simulation Techniques for Communication Networks
16.618 Performance of Wireless Communications Networks
16.661 Local Area /Computer Networking
16.685 Statistical Theory of Communications
16.687 Stochastic Estimation
16.688 Theoretical Acoustics
91.555 Computer Networks
91.563 Data Communications I
91.564 Data Communications II

In addition to the required three core courses, three courses from the following list are recommended depending upon whether a thesis is selected or not.

Communications Engineering

16.533	Microwave Engineering
16.546	Computer Telecommunications
16.548	Coding and Information Theory
16.571	Radar Systems
16.582	Wireless Communications
16.586	Stochastic Modeling in Telecommunications
16.617	Modeling and Simulation Techniques for Communication Networks
16.618	Performance of Wireless Communications Networks
16.661	Local Area/Computer Networking
16.684	Time Series Analysis
16.685	Statistical Theory of Communications
16.687	Stochastic Estimation
91.563	Data Communications I
91.564	Data Communications II

Power and Energy Engineering

16.514	Power Systems Transmission
16.515	Power Electronics
16.516	Advanced Machine Theory
16.519	Engineering of Submicron Machines
16.523	Introduction to Solid State Electronics
16.525	Power Systems Distribution
16.528	Alternative Energy Sources
16.529	Electric Vehicle Technology
16.615	Solid State Drives Systems
16.616	Computational Power Analysis

Opto-Electronics

16.507	Electromagnetic Waves and Materials
16.508	Quantum Electronics for engineers
16.532	Computational Electromagnetics
16.590	Fiber Optic Communications
16.595	Solid State Electronics
16.607	Electromagnetics of Complex Media
95.631	Non-Linear Optics

Opto-Electronics is an option in cooperation with the Department of Physics, and may be pursued by students enrolled in the MS Eng in EE program. This option contains required and recommended courses designed to provide a fundamental background in optical devices and systems, as well as in optical physics and in the electro-optical properties of materials.

In addition to the required three core courses, students pursuing this option must take 16.568 Electro-Optics and Integrated Optics and two other courses from the above list.

Other concentrations in Electrical Engineering can be found from the clusters of courses specified as ECE certificates in the "Graduate Certificates" section.

Concentration courses in Computer Engineering

Computer Networking and Distributed Systems

16.558	World Wide Web programming
16.583	Network Design: Principles, Protocols and Applications
16.590	Fiber Optic Communications
16.657	High-Speed Integrated Networks: Design and Evaluations
16.658	Computer Network Security
16.659	Distributed Systems
16.660	Mobile IP Networking
16.661	Local Area/Computer Networking
16.666	Storage Area Networks

Computing and Embedded Systems Hardware and Architecture

16.502	VLSI Design
16.504	VLSI Fabrication
16.517	MMIC Design and Fabrication
16.550	Advanced Digital Systems Design
16.552	Microprocessors II and Embedded Systems
16.553	Software Engineering
16.557	Object Oriented Design
16.572	Embedded Real-time Systems
16.574	Advanced Logic Design
16.575	FPGA Logic Design Techniques
16.650	Advanced Computing Systems Hardware Architecture
16.652	Parallel and Multi-processor Architecture
16.656	Fault Tolerance Systems Design
16.663	Compiler Structures

Artificial and Machine Intelligence

16.511	Medical Imaging Diagnosis
16.552	Microprocessors II and Embedded Systems
16.553	Software Engineering
16.554	Voice Recognition, Processing and Computer Sound Drivers
16.556	Robotics
16.557	Object Oriented Design
16.572	Embedded Real-time Systems
16.651	Computer Vision
16.653	Artificial Intelligence and Machine Learning
16.750	Advanced Robotics and Machine Intelligence

Multimedia Digital Signal and Image Processing and Applications

16.502	VLSI Design
16.510	Digital Signal processing
16.511	Medical Imaging Diagnosis
16.521	Real Time DSP
16.553	Software Engineering
16.554	Voice Recognition, Processing and Computer Sound Drivers
16.572	Embedded Real-time Systems
16.581	Computer Vision and Digital Image Processing

Electrical & Computer Doctoral Programs

There are two types of doctoral degrees, the Doctor of Philosphy (Ph.D) and the Doctor of Engineering (D.Eng). The former is more research-oriented while the latter is more industrially-oriented. The Department offers both types of doctoral degrees in both EE and CP. The available degree programs are:

Doctor of Philosophy (Ph.D) Program in Electrical Engineering
Doctor of Philosophy (Ph.D.) Program in Computer Engineering
Doctor of Engineering (DEng) Program in Electrical Engineering
Doctor of Engineering (DEng) Program in Computer Engineerinq

The primary difference between the two types of doctoral programs is the requirement for 9 management credits for the D.Eng degrees. There may also be differences in the content of the dissertations.

Objective

The primary goal of the Doctororal Programs is to develop research engineers with the ability to produce new engineering knowledge. The program includes advanced graduate coursework in electrical engineering and allied subjects, a non-technical component (in the case of the D.Eng), and research culminating in a doctoral dissertation. a

A complete description of the doctoral program is found in the Department of Electrical and Computer Engineering Doctoral Student Handbook which is updated annually and available from the department office.

Admission Requirements

Applicants must have a BS or MS degree in Electrical Engineering or Computer Engineering or their equivalent from a recognized College or University with an acceptable quality of prior academic work. Applicants must submit official transcripts of all prior undergraduate and graduate courses. Each applicant must submit an official report of Graduate Record Examination (GRE) scores for verbal, quantitative, and analytical examinations. The TOEFL exam is required for students from abroad whose native language is not English.

Plan of Study

Each student entering the program must develop a plan of study in consultation with his/her advisor.

Residency Requirement

One year of full-time residence is required of all students in the program.

Program Duration

The time for graduation for full-time students is expected to range from a minimum of three and a half years to a maximum of five years after BS Eng and a minimum of two and a half years to a maximum of four years after MS Eng.

Transfer Credit

Up to 24 semester credits in graduate courses in Electrical Engineering and allied subjects are transferable to the doctoral program upon approval by the Doctor of Engineering Committee of the Department of Electrical and Computer Engineering.

Candidacy Requirements

1. Qualifying Examination

The qualifying examination is a written exam which is conducted annually in late November. Students accepted to the Doctoral Program must take the qualifying examination within one year of their acceptance.

2. Thesis Proposal and Oral Exam in Area of Concentration

Having passed the qualifying examination, a student may submit his/her dissertation proposal and defend the proposal before the Doctoral Committee. The proposal examination will also include an oral examination on topics connected with the student's area of research. On passing this examination, the student's name will be submitted for acceptance as a candidate for the Doctoral Degree. Admission to candidacy status does not guarantee the obtaining of the degree.

Academic Requirements

1. Credit Requirements

The Doctor of Philosophy (Ph.D.) and Doctor of Engineering (D.Eng) degrees require completion of a minimum of 63 semester hours of academic credit beyond the Bachelor of Science degree. A typical program consists of the following:

Ph.D	
ECE and Allied Subjects	42 (42)
Thesis	21 (22)
Total credit hours	63 (63)
D.Eng	
ECE and Allied Subjects	33 (33)
Thesis	21 (22)
Non-Technical Component	9 (8)
Total credit hours	63 (63)

The Doctoral Program Coordinator of the Department of Electrical and Computer Engineering will assist students in selecting courses to meet the non-technical component of the Doctor of Engineering program.

2. Core Requirements

Required Core Courses for Ph.D or D.Eng in Electrical Engineering

16.507 Electromagnetic Waves and Materials
16.508 Quantum Electronics for Engineers
16.509 Linear Systems Analysis
16.513 Control Systems
16.515 Power Electronics
16.520 Computer-Aided Engineering Analysis
16.543 Introduction to Communications Theory
16.584 Probability and Random Processes
16.595 Solid State Electronics

Students in Electrical Engineering must take three of the above courses that may be pertinent to their area of concentration.

Required Core Courses for Ph.D or D.Eng in Computer Engineering

16.561 Computer Architecture and Design
16.573 Operating Systems and Kernel Design
16.562 VHDL/Verilog Synthesis and Design (Previous course number 16.602)

3. Concentration Requirement

Generally a concentration is defined by a coordinated and approved sequence of at least four graduate courses. Each student can work out a concentration either with the doctoral coordinator or with his/her academic advisor. Completion of a concentration is mandatory. The course sequences in the concentrations serve as a starting point for establishing a program of study in consultation with the student's academic advisor to meet his/her educational objectives. It is expected that the courses comprising the concentration will complement the work the student will undertake in fulfillment of the research requirement. Indications of some of these concentrations are given under the programs of Master of Science in Engineering.

A concentration in electro-physics is also available.

4. Grade-Point Average (GPA) Requirement

To successfully complete the program, a student must achieve a cumulative grade-point average (GPA) of at least 3.25 in all course work.

5. Research Requirement and Dissertation

Each student is required to do a research internship for at least one year in industry, government, or at the University. The purpose of the internship is to place the student in a realistic engineering setting in which he/she will function as a responsible engineer and carry out the research work required for the dissertation. During the internship, the student must maintain close contact with his/her academic advisor. A written dissertation must be submitted and defended orally.

Graduate Certificates

Graduate certificate programs are ideal for bachelor's degree-prepared engineers who wish to continue their studies without making the commitment of a master's program. Students may want to brush-up on new developments in their field or investigate another specialty. Certificates are earned by taking four courses from a list associated with each certificate.

Electrical and Computer Engineering

- Communications engineering
- Microwave and wireless engineering
- Stochastic systems
- VLSI and microelectronics

Interdisciplinary

- Biomedical engineering
- Energy conversion
- Integrated engineering systems
- Nanotechnology
- Photonics and optoelectronics
- telecommunications

Each of these certificates are described below and include the name and contact information of the certificate coordinator.

Communications Engineering Certificate

Electrical and Computer Engineering Department
Dr. Kavitha Chandra 978-934-3356
kavitha_chandra@uml.edu

This certificate provides a fundamental background in the understanding of information transmission, statistical properties of signals and noise, and both analog and digital modulation/demodulation techniques. Advanced topics in modern communications and the characterization of communication channels are covered in optional courses in coding, error correction, information measures, stochastic system modeling and wireless communications. The holder of the certificate will have both analytical and practical competence to contribute significantly to the design and development of new and updated communications systems.

Required Courses:

16.543 Communications Theory
16.584 Probability and Random Processes

Elective Courses: (Choose two of the following)

16.548 Coding and Information Theory
16.582 Wireless Communication
16.618 Performance of Wireless Communications Networks
16.685 Statistical Communication Theory
16.687 Applied Stochastic Estimation

Microwave and Wireless Engineering Certificate

Electrical and Computer Engineering Department
Dr. Tenneti C. Rao 978-934-3323
tenneti_rao@uml.edu

Wireless technologies are of increasing importance in a variety of personal communications and control applications. The certificate is open to students who have an interest in learning the fundamentals and engineering applications of radio wave and microwave devices and systems. The integrated set of courses offers graduate level skills and knowledge which will provide a background for those wishing to participate in this rapidly expanding field. The certificate is open to students with a BS degree in electrical engineering or in related disciplines such as physics or electronics engineering technology with an appropriate background in electromagnetics.

Required Courses:

16.531 Radio Frequency (RF) Design
16.532 Microwave Engineering
16.582 Wireless Communications

Elective Courses: (Choose one of the following)

16.506 Antenna Design
16.571 Radar System
16.618 Performance of Wireless Communication Networks

Stochastic Systems Certificate

Electrical and Computer Engineering Department
Dr. Oliver Ibe 978-934-3118
oliver_ibe@uml.edu

This certificate provides a thorough grounding in the modeling of signals represented as random functions of time. A background in linear system theory, signal transforms and the theory of probability and random processes is given. The certificate is completed by choosing specialized courses in time series analysis, statistical communication theory or applied stochastic estimation. These courses deal with the estimation of signals and of noise using a variety of mathematical models such as likelihood and entropy based techniques, matched, adaptive and nonlinear filtering of signals. The holder of this certificate will have the analytical and practical competence to design for and evaluate probabilistic issues in communications, complex systems, and/or networks.

Required Courses:

16.584 Probability and Random Processes
16.711: Special Topics in ECE: Advanced Markov Methods

Elective Courses: (Choose two of the following)

16.509 Linear Systems Analysis
16.543 Theory of Communication
16.687 Applied Stochastic Estimation

VLSI & Microlectronics Certificate
Department of Electrical & Computer Engineering
Dr. Kanti Prasad 978-934-3326
Kanti_prasad@uml.edu

The purpose of this certificate program is to provide essential background in solid state physical electronics and very large scale integrated (VLSI) circuit fabrication. These courses, combined with two electives, will provide a customized background to the subject but with sufficient depth in an area of choice to provide tangible useful expertise.

Required Courses: (Choose two of the following)

16.502 VLSI Design
16.595 Solid State Electronics
16.504 VLSI Fabrication
16.508 Quantum Electronics for Engineers

Elective Courses: (Choose two of the following)

16.502 VLSI Design
16.505 Microwave Electronics
16.507 Electromagnetic Waves and Materials
16.508 Quantum Electronics for Engineers
16.517 MMIC Design and Fabrication
16.565 Analog Devices
16.568 Electro Optics and Integrated Optics

Biomedical Engineering Certificate
Electrical & Computer Engineering Department
Dr. Mufeed Mah'd 978-934-3317
mufeed_mahd@uml.edu

Image data are of increasing importance in Biomedical Engineering and Biotechnology. The application of microelectronic circuitry, high performance processors, and improved algorithms based on advanced mathematics has resulted in innovative new methodologies to acquire and process image data, permitting visualization, quantification, and functional analysis of tissues and organs. The Biomedical Engineering Graduate Certificate is a multidisciplinary program, spanning courses in several departments in the College of Engineering including Departments of Electrical and Computer Engineering, Plastic Engineering, Chemical and Nuclear Engineering, as well as the Biomedical Engineering and Biotechnology program. The certificate provides an excellent opportunity for educational experience to learn the principles and applications of imaging technology. It is a coordinated program of courses, seminars, and laboratory experiences jointly offered by the participating departments.

Required Courses:

16.511 Medical Imaging Diagnosis
IB.500 Introduction to Biomedical Engineering and Biotechnology

Elective Courses: (Choose two of the following)

16.560 Biomedical Instrumentation
19.531 Occupational Biomechanics
24.542 Microscopy of Advanced Materials
24.541 AFM and X-ray Diffraction Analysis of Advanced Materials
26.553 Polymers in Medicine I
26.575 Biomaterials

Energy Conversion Certificate

Electrical and Computer Engineering Department
Dr. Ziyad Salameh 978-934-3333
Ziyad_salameh@uml.edu

Energy conversion is a discipline that spans across three departments: Electrical, Mechanical and Chemical & Nuclear Engineering. Interest is rising for practical applications in the housing industry to supply houses with clean sources of energy to meet electrical supply needs, as well as for space heating/ cooling. All renewable energy sources will be considered (e.g. wind energy and photovoltaics). Information about batteries, battery charging stations, battery chargers and energy conversion devices (such as rectifiers, inverters, choppers, controllers) is presented as related to the development of low emission vehicles.

Choose four of the following courses:

16.515 Power Electronics
16.525 Power Systems Distribution
16.528 Alternative Energy Sources
16.529 Electric Vehicle Technology
22.521 Fundamentals of Solar Energy Engineering
22.527 Solar Energy Engineering

Integrated Engineering Systems Certificate

Applied Physics, Computer Engineering, Computer Science, Electrical Engineering, Materials Engineering, Mechanical Engineering, Plastics Engineering Departments
Dr. Anh Tran 978-934-3322
Anh_Tran@uml.edu

As companies increasingly undertake engineering projects that bring together a wide range of disciplines for manufacturing an integrated product, it is often necessary to assemble teams of experts in these various disciplines, and prepare managers who have a fundamental, overall understanding of several different engineering areas. The certificate is designed to respond to the need for trained professionals who are responsible for managing complex engineering systems integrating algorithms, information, software and hardware. Completion of certificate courses in areas complementary to the individual's specific training will serve as an important starting point for engineering managers (and prospective managers) who need to solve complex interdisciplinary problems at the interfaces of electrical, computer, mechanical, materials engineering, and computer science and applied physics.

The program consists of six clusters: 1) Applied Physics; 2) Computer Engineering; 3) Computer Science; 4) Electrical Engineering; 5) Materials Engineering; and 6) Mechanical Engineering. Within each cluster, there are a number of carefully selected courses ranging from introductory graduate level to more advanced, specialized electives.

Students must successfully complete four courses, one or two of which may be taken in their area of expertise. The remaining courses must be taken in separate and different cluster areas. Courses are selected in consultation with one (or more) graduate program coordinators to best meet the student's needs in terms of background, interests, and work requirements. It may be necessary for students to take prerequisite course(s) if they do not have appropriate backgrounds for a particular cluster course.

Cluster Areas and Designated Courses:

Applied Physics

95.553 Electromagnetism I
95.554 Electromagnetism II
95.540 Image Processing (4 credits)
95.578 Integrated Optics: Wave Guide and Lasers
95.535 Introduction of Quantum Mechanics I
95.547 Laser Physics and Applications
95.538 Physical Optics and Waves
95.577 Solid State Electronic and Opto-Electronic Devices
95.521 Statistical Thermodynamics

Computer Engineering

16.550 Advanced Digital System Design
16.561 Computer Architecture Design
16.581 Computer Vision and Digital Image Processing
16.510 Digital Signal Processing
16.572 Embedded Real-Time Systems
16.575 FPGA Logic Design Techniques
16.552 Microprocessors Systems II and Embedded Systems
16.582 Network Design: Principles, Protocols, and Applications
16.573 Operating Systems and Kernel Design
16.521 Real Time DSP
16.502 VLSI Design
16.504 VLSI Fabrication

Computer Science

91.561 Computer Security I
91.562 Computer Security II
91.563 Data Communications I
91.564 Data Communications II
91.549 Mobile Robots
91.515 Operating Systems I
91.516 Operating Systems II
91.548 Robot Design
91.523 Software Engineering I
91.524 Software Engineering II

Electrical Engineering

16.528 Alternative Energy Sources
16.506 Antenna Theory and Design
16.532 Computational Electromagnetics
16.513 Control Systems
16.529 Electric Vehicle Technology
16.507 Electromagnetic Waves and Materials
16.512 Electronic Materials
16.519 Engineering of Submicron Machines
16.590 Fiber Optic Communications and Networks
16.543 Theory of Communication
16.509 Linear System Analysis
16.505 Microwave Electronics
16.533 Microwave Engineering
16.515 Power Electronics
16.584 Probability and Random Processes
16.571 Radar Systems
16.517 MMIC Design and Fabrication

Materials Engineering

26.544 Advanced Plastics Materials
10.506 Interfacial Science and Engineering and Colloids
10.507 Material Science and Engineering
26.503 Mechanical Behavior of Polymers
10.523 Nanodevices and Electronic Materials
10.527 Nanomaterials Science and Engineering
10.541 Nanostructural Characterization by SEM, TEM, and AFM
26.518 Plastics Product Design

Mechanical Engineering

22.512 Applied Finite Element Analysis
22.571 Concurrent Engineering and Quality
22.523 Cooling of Electronic Equipment
22.574 Design for Reliability Engineering
22.516 Experimental Modal Analysis
22.524 Fundamentals of Acoustics
22.575 Industrial Design of Experiments
22.573 Manufacturing Systems Engineering
22.591 Mechanical Behavior of Materials
22.515 Modal Analysis- Theoretical Methods
22.579 Robotics
22.562 Solid Mechanics
22.527 Solar Systems Engineering
22.550 Vibrations

Nanotechnology Certificate

Civil & Environmental, Mechanical, Plastics Engineering Departments
Dr. Jackie Zhang 978-934-2287
jackie_zhang@uml.edu

The program will provide students with a fundamental knowledge of nanotechnology and is intended to respond to the increasing demand for trained professionals in nanoscience and technology. The certificate is designed for students with a background in chemistry, physics, biology, or any branch of engineering who want nanotechnology and nanomanufacturing workforce preparation. Students may focus on a concentration area based on their interests and background. Courses in each concentration area are carefully designed to provide both analytical and practical competence. Students may take any combination from the electives list.

Core Courses - Required:

25.550 Introduction to Nanotechnology

Core Courses: (Choose one):

10.541 Nanostructural Characterization by SEM, TEM, and AFM
84.510 Electron Microscopy of Advanced Materials
84.525 Analysis of Advanced Materials

Elective Courses (choose two courses):

Materials

10.527 Nanomaterials Science and Engineering
10.506 Interfacial Science and Engineering and Colloids
22.591 Mechanical Behavior of Materials
26.513 New Plastics Materials
26.598 Smart Polymers

Manufacturing

10.523 Electronic Materials Processing
10.535 Cell & Microbe Cultivation
10.545 Isolation & Purification of Biotech Products
16.504 VLSI Fabrication
26.502 New Plastics Processing Techniques
26.578 Advanced Polymer Processing
xx.xxx Processing of Nanocomposites

Design and Devices

16.710: Special Topics in ECE: Nanoelectronics
16.502 VSLI Design
16.512 Electronic Materials
16.508 Quantum Electronics for Engineers

Health and Environmental Impacts

19.514 Aerosol Science
19.525 Industrial Hygiene and Ergonomics
19.557 Toxic Use Reduction
19.610 Exposure Assessment
19.617 Measurements of Airborne Contaminants
19.503 Toxicology and Health

Photonics & Opto-Electronic Devices Certificate
Physics Department and Electrical & Computer Engineering Department
Dr. James Egan 978-934-3774 / 978-934-3300
James_egan@uml.edu

The certificate is offered jointly by the Electrical & Computer Engineering & Physics Departments and reflects the strong interests in the physics and technologies of electro-optics. Extensive research facilities include: new materials growth (molecular beam epitaxy) and device fabrication and testing laboratories.

Required Courses:

95.577 Solid State Electronic & Opto-electronic Devices
and
95.539 Electro-optics
OR
16.595 Solid State Electronics
and
16.568 Electro Optics and Integrated Optics

Elective Courses: (choose two of the following):

16.507 Electromagnetic Waves and Materials
16.508 Quantum Electronics for Engineers
16.590 Fiber Optic Communications
16.607 Electromagnetics of Complex Media
16.669 Opto Electronic Devices
95.547 Laser Physics & Applications
95.631 Nonlinear Optics
95.578 Integrated Optics: Wave Guides & Lasers

Telecommunications Certificate
Computer Science Department
Dr. Byungki Kim 978-934-3617
byungki_kim@uml.edu

The graduate certificate consists of courses from both the Computer Science and Electrical Engineering Departments. It is intended for students who hold a baccalaureate degree in science or engineering and who wish to concentrate on hardware/software issues pertaining to telecommunications.

Required Courses:
16.543 Theory of Communication
91.555 Computer Networks
91.563 Data Communications I

Plus One Approved Elective

Electrical Engineering Course Descriptions

Undergraduate Courses

16.100 Introduction to Electrical and Computer Engineering

This introductory course is designed to expose students to many of the new developments in Electrical and Computer Engineering, especially those on-going in the Department. It will also provide information about co-op opportunities and career planning, while also allowing faculty in the Department to describe their courses and answer questions. Prerequisite: none.

16.201 Circuit Theory I

Terminal characteristics of ideal elements, active and passive. Ohm's law and Kirchhoff's Laws. Introduction to network topology, independent variables, loop and nodal analysis with matrix methods. Definition and consequences of linearity. Superposition theorem. Concept of excitation and response. Passive equivalent circuits; active equivalent circuits. Thevenin's and Norton's theorems. Ideal inductance and capacitance, volt-ampere characteristics, energy relations, First-order transients: initial conditions, natural response, and natural frequencies. Network response to unit step function and unit impulse. Second-order transients: RLC circuits, natural frequencies and the complex-frequency s-plane. Introduction to matrices and their use in circuit analysis. Prerequisite: GPA at least 2.000, 92.132 Grade "C" or better, Co-requisite: 16.207.

16.202 Circuit Theory II

Sinusoidal forcing function, complex numbers, phasors, sinusoidal steady-state conditions. Impedance, average real power, reactive power and rms values. Exponential forcing function, poles and zeros in the s-plane, concept of the system function and its use in determining the forced response and natural behavior of circuits. Frequency response and resonance, reactance cancellation and concept of s-plane vectors. Thevenin's and Norton's theorems, superposition, reciprocity, and maximum power in the frequency domain. Impedance and admittance and hybrid parameters for a two-port network. Magnetic coupling, mutual inductance, ideal transformer. Prerequisite: 16.201. Co-requisite: 16.208.

16.207 Basic EE I Laboratory

Experimental work designed to verify theory and to acquaint students with electrical measurement techniques: experiments on meters, bridges, and oscilloscopes. Experiments are correlated with course 16.201 and concern: resistive measurements, Kirchhoff's laws, network theorems, conservation of power and maximum power transfer, inductance and capacitance, and first and second-order transients, operational amplifiers. Co-requisite: 16.201.

16.208 Basic EE II Laboratory

Experimental work, designed to emphasize electrical measurement techniques of linear systems with time-varying signals. Waveform measurements with ac meters as well as advanced use of the digital oscilloscope. Experiments are integrated with course 16.202. Experiments cover: Kirchhoff's laws for phasors, magnitude and phase measurements of impedance, network theorems, frequency response, pole and zero location, resonance, inductance, statistical variation of components, modeling with MATLAB. Prerequisite: 16.207. Co-requisite: 16.202.

16.211/213 Fundamentals of Electricity

An introduction to direct current and alternating current analysis of electric circuits, with emphasis on energy and power. Design and use of multirange voltmeters, ammeters, and ohmmeters. Use of bridges and oscilloscopes. Phasor analysis of AC circuits, Trigonometric Fourier series, and BODE plots. Transformers, relays, and solenoids. DC and AC motors and generators. Semiconductor devices: p-n junctions, diodes, Zener diodes, bipolar transistors, JFETs, MOSFETs. Amplifiers. Operational amplifiers and their applications. Introduction to digital logic including minimization techniques. Not for ECE majors. Prerequisite: 92.132.

16.212 Fundamentals of Electricity Laboratory

Laboratory for 16.211/213. Experiments designed to correlate with the topics covered in the course 16.211. Reinforcement of various concepts through measurement techniques. Experiments cover: measurement of current and voltage, series and parallel DC circuits; superposition theorem, Thevenin's theorem, use of oscilloscope, impedance measurements of RLC, frequency response of RL, RC networks, diode operations, clipper actions, rectifiers and operational amplifiers. Co-requisite: 16.211.

16.214 Fundamentals of Electricity

Similar to 16.211 but tailored for Sound Recording Technology students only.

16.216 ECE Application Programming

Introduces C programming for engineers. Covers fundamentals of procedural programming with applications in Electrical and Computer Engineering and embedded systems. Topics include variables, expressions and statements, console input/output, modularization and functions, arrays, pointers and strings, algorithms, structures, and file input/output. Introduces working with C at the bit manipulation level. Laboratories include designing and programming engineering applications. Prerequisite: 25.108.

16.233 Principles and History of Radio

Intended primarily for students majoring in the liberal arts. The course develops the theory of electricity from an historical perspective. Sufficient background in circuit theory, resonance, field theory and radio waves is given to provide an understanding of the principles of radio from its antecedents in the nineteenth century through the invention of the transistor in the mid twentieth century. The fundamental contributions of, for example Volta, Oersted, Morse, Maxwell, Faraday, Hertz, Lodge, and Marconi are considered. In the present century the technical advances of such figures as de Forest, Fleming, Fessenden, Armstrong and Shockley are studied. The growth, regulation and culture of American broadcasting are also central to the course. Laboratory work is required and students may use this course toward fulfilling the General Education (science/experimental component) requirement of the University. Not open to students in the College of Engineering. Prerequisite: none.

16.265 Logic Design I

Number systems and computer codes. Switching algebra. Canonical and fundamental forms of switching functions. Minimization of switching functions. Two-level and multi-level digital circuits. Decoder, encoders, multiplexers, and demultiplexers. Design of combinational circuits using SSI, MSI and programmable logic devices. Latches and flip-flops. Registers and counters. Analysis and synthesis of synchronous sequential circuits. Design of more complex circuits: datapath and control. Prerequisite: 25.108 or 91.101.

16.311 Electronics I Laboratory

Laboratory experiments coordinated with the subject matter of 16.365. Characteristics and use of electronic instrumentation for making measurements on electronic circuits. Methods of designing and characterizing diode and transistor circuits. Analysis of performance characteristics of digital and linear semiconductor circuits, including logic elements and amplifiers. Design and construction of circuits using monolithic op amps. Co-requisite: 16.365.

16.312 Electronics II Laboratory

Laboratory experiments coordinated with the subject matter of 16.366. High-frequency characteristics of transistors and transistor amplifiers. Feedback in electronic circuits. Electronic oscillators. Differential amplifiers. Properties of linear IC operational amplifiers and their application in amplifier circuits and waveform generation circuits. Linear circuit design and analysis. Prerequisite: 16.311. Co-requisite: 16.366.

16.317 Microprocessor Systems Design I

This three credit course provides an introduction to microprocessors. It uses assembly language to develop a foundation on the hardware, which executes a program. Memory and I/O interface design and programming. Study of microprocessor and its basic support components, including CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, serial I/O devices, and interrupt control devices. Laboratories directly related to microprocessor functions and its interfaces. Prerequisites: 16.265 and 16.365.

16.322 Data Structures and Algorithms

Introduction to object-oriented programming using C++, including: C++ input/output operators, default arguments, function overloading, strings, classes, dynamic memory allocation, and templates, Covers algorithms and their performance analysis, data structures, abstraction, and encapsulation. Introduces structures and their physical storage representation. Studies vectors, stacks, queues, linked lists, trees, graphs, heaps, priority queues, and hashing. Discusses efficient sorting (quicksort and heapsort) and introduces experimental analysis of algorithms as applied to engineering applications. Examines several design issues, including selection of data structures based on what operations need to be optimized (insertion, deletion, traversal, searching, sorting, evaluation), encapsulation of algorithms using class and template techniques, and how and when to use recursion (versus explicit stack-based techniques). Laboratories include programming of data structures in C++ applied to Engineering. Prerequisite: 16.216.

16.333 Chemistry and Engineering of Electronic Materials

The production and processing of materials into finished products constitutes a large part of the present economy. To prepare students for to use of a variety of traditional and new materials, this course will cover: atomic structure and chemical bonding, crystal geometry and defects, mechanical properties and phase diagrams of metals and alloys, electrical and optical properties of semiconductors, ceramics and polymers; brief description of electronic, quantum electronic and photonic devices; benefits and difficulties of materials design with decreasing dimensions from millimeters to micrometers and to nanometers. Prerequisites: 92.132 and 95.144.

16.339 Principles of Communication Systems

An introduction to communication systems. Introduces modulations and demodulations; noise and signal-to-noise ratio analysis; the measure of information, channel capacity. Topics include bit error rates, coding and signal orthogonality, modulation, transmission, detection techniques for data systems, multiplexing (in space, time and frequency), access techniques, spread spectrum and data encryption and their uses in modern data communications systems. Prerequisite: 16.362.

16.355 Electromechanics

Alternating current circuits, three phase circuits, basics of electromagnetic field theory, magnetic circuits, inductance, electromechanical energy conversion. Ideal transformer, iron-core transformer, voltage regulation, efficiency equivalent circuit, and three phase transformers. Induction machine construction, equivalent circuit, torque speed characteristics, and single phase motors. Synchronous machine construction, equivalent circuit, power relationships phasor diagrams, and synchronous motors. Direct current machines construction, types, efficiency, power flow diagram, and external characteristics. Prerequisites: 16.202 and 95.144.

16.360 Engineering Electromagnetics I

Waves and Phasors, Transmission lines as Distributed Circuits, Smith Chart Calculations, Impedance Matching, Transients on Transmission Lines, Vector Analysis, Electrostatics and Capacitance, Steady current flow in conductors and Resistance, Magnetostatics and Inductance. Prerequisite: 16.202.

16.362 Signals & Systems I

A study of various continuous voltage/current time functions and their applications to linear time-invariant electrical systems. Review of pertinent topics from 16.202 such as system functions, S-plane concepts and complete responses. Step, ramp and impulse responses of linear circuits. Sifting integrals. Types of analog filter responses. Designs for Butterworth and Chebyshev filters. Fourier Analysis, Fourier Transforms, Convolution, Laplace Transforms, Parseval's Theorem. Prerequisites: 16.202 and 92.236.

16.363 Introduction to Probability and Random Processes

This course employing probabilistic methods of signal and system analysis (an extension of 16.362) considers the random nature of the world faced by electrical engineers. The course addresses the issues of the nature and characterization of random events, especially noise and its effect on systems. The course is divided into three parts, 1) Introduction to discrete and continuous probability 2) Introduction to statistical methods and 3) random signals and noise and the response of linear systems to random signals. There will be frequent use of Monte-Carlo simulation techniques on the computer to allow students to verify theory and to learn the important technique of simulation. Applications of theory to manufacturing and reliability, noise analysis, spectral analysis, data communication, data collection, and system design will be presented. Prerequisite: 16.362. (Formerly known at Signals and Systems II)

16.364 Engineering Mathematics

The course covers the main topics in complex variables and applications including: Complex numbers, Argand plane, derivatives of complex numbers, limits and continuity, derivative and Cauchy Riemann conditions, analytic functions, integration in the complex plane, Cauchy's integral formula, infinite series for complex variables, Taylor series, Laurent series, residue theory, evaluation of integrals around indented contours. Additionally, the following topics in linear algebra will be covered: Linear vector spaces, matrices and determinants, eigenvalues and eigenvectors. Prerequisites: 16.201 and 92.236.

16.365 Electronics I

A brief introduction to solid-state physics, leading to discussion of physical characteristics of p-n junction diodes, bipolar junction transistors, and field-effect transistors: active, saturated, and cut-off models of bipolar transistors and triode, constant current, and cut-off models of MOSFETs. Circuit models for diodes, and diode applications. Circuit models for transistors, and transistor applications in bipolar and MOS digital circuits and low-frequency amplifier circuits. Analysis of digital circuits and linear circuits based on application of circuit models of devices and circuit theory. Prerequisites: 16.202, 95.144 and either Calculus III or Differential equations. Co-requisite: 16.311.

16.366 Electronics II

A continuation of 16.365 with discussion of differential amplifiers, operational amplifiers and op amp applications, transistor amplifiers at very high frequencies; direct-coupled and band pass amplifiers; small and large signal amplifiers; feedback amplifiers and oscillators. Active filters, wave form generation circuits including Schmitt trigger, multiplexers, and A/D and D/A converters. Circuit design employing integrated circuit operational amplifiers and discrete devices. Circuit analysis using SPICE. An electronic design project constitutes a major part of the course. Prerequisite: 16.365. Co-requisite: 16.312.

16.399 Capstone Proposal

This course discusses and presents the non-technical tools and procedures for bringing a potential product from the idea or basic concept stage through final design and to market. Fundamentals of market research, product safety and liability concerns, necessary technical communication skills. Economic concerns, patent, application procedures, design procedures and people skills necessary to be part of an engineering team. Prerequisites: 16.312, 16.317, 16.363, 16.366, and less than 30 credits remaining at the time of registration to complete major. Co-requisite: 16.400

16.400 Engineering Topics

This course introduces to the seniors developing the capstone proposal important concepts such as economics, environmental, sustainability, manufacturability, ethical, health, safety, social and political constraints and how these are related to the overall engineering processes. These will be used as an integral part of their capstone projects. Co-requisite: 16.399.

16.403 Microwave Design Theory

An introductory course in the analysis and design of passive microwave circuits beginning with a review of time-varying electromagnetic field concepts and transmission lines. Smith Chart problems; single and double stub matching; impedance transformer design; maximally flat and Chebyshev transformers; microstrip transmission lines, slot lines, coplanar lines; rectangular and circular waveguides; waveguide windows and their use in impedance matching; design of directional couplers; features of weak and strong couplings; microwave filter design; characteristics of low-pass, high-pass, band-pass, band-stop filter designs; two-port network representation of junctions; Z and Y parameters, ABCD parameters, scattering matrix; microwave measurements; measurement of VSWR, complex impedance, dielectric constant, attenuation, and power. A design project constitutes a major part of the course. Prerequisite: 16.461.

16.409/16.410/16.412 Project Laboratory

The purpose of this course is to provide an opportunity for qualified ECE students to investigate specific areas of interest. The actual project undertaken may be software or hardware oriented. The most important characteristics of the projects are that the end results represent independent study and that they are research and development oriented, and that they are accomplished in an engineering environment. Design reviews and progress reports are expected for each project. A final formal report to be permanently filed in the ECE Department is required for each project. Prerequisites: at least three courses from 16.355, 16.360, 16.362, 16.365, and 16.366.

16.411/16.511 Medical Diagnostic Imaging

This course covers the physics and electrical engineering aspects of how signals are acquired from which images will be formed, and the principal methods by which the signals are processed to form useful medical diagnostic images. Modalities studied include: x-rays, ultra-sound, computed tomography, and magnetic resonance imaging. The principles of signal processing via Fourier transform will be reviewed. Noise and other artifacts that degrade the medical diagnostic of images are considered. MATLAB is heavily used in simulation and verification. . Prerequisite: 16.362.

16.413 Linear Feedback Systems

Concepts of feedback; open loop and closed loop systems. Feedback in electrical and mechanical systems. Mathematical models of systems and linear approximations. Transfer functions of linear systems, block diagrams and signal flow graphs. Sensitivity, control of transient response, disturbance signals. Time domain performance: steady state errors, performance indices. Stability related to s-plane location of the roots of the characteristic equation. Routh-Hurwitz criterion. Graphical analysis techniques: root locus, frequency response as polar plot and Bode diagrams. Closed loop frequency response. A control system design project is included in the course. Prerequisites: 16.362 and 16.364.

16.418 Wireless Communications

Cellular systems and design principles, co-channel and adjacent channel interference, mobile radio propagation and determination of large scale path loss, propagation mechanisms like reflection, diffraction and scattering, outdoor propagation models, Okumura and Hata models, small scale fading and multipath, Doppler shift and effects, statistical models for multipath, digital modulation techniques QPSK, DPSK, GMSK, multiple access techniques, TDMA, FDMA, CDMA, spread spectrum techniques, frequency hopped systems, wireless systems and worldwide standards. Prerequisite: 16.360.

16.420/16.520 Computers in Engineering Analysis and Design

An advanced programming course, which considers the digital computer as a tool for solving significant engineering problems. The course is based on a specific area in engineering which will be selected from such topics as digital and image processing, spectral estimation, optimization techniques, etc. Typical algorithms related to the specific topic will be studied. User oriented programs or subroutine packages will be developed in a project. Prerequisite: senior standing in ECE.

16.421/16.521 Real-Time Digital Signal Processing

This course provides an introduction to real-time digital signal processing techniques using ADSP-21161, 21262, BF561, TS201S floating/fixed point processors. This is a practical course with 'hands on' training using the latest software development tools. First the core elements of the processor (computational units, data address generators, program sequencer) are examined in detail along with the relevant assembly code instructions. Internal and external memory configuration is also discussed. Advanced instructions are presented with a follow on lab on code optimization. The I/O peripherals (SPORTS, link ports, external port) are discussed in detail along with DMA operation between these peripherals and internal memory. Throughout the course, the various aspects of the software development process using the latest tools are discussed including setting up and building projects, assembly language programming, code debugging, simulation, tool support for code overlays and shared memory, and 'C' programming support. Hardware development tools, such as evaluation boards and ICE's are introduced with a follow on hardware/software lab where the student develops a simple interrupt driven application for a hardware target. Prerequisites: 16.362 and C or Assembly programming knowledge.

16.423/16.523 Introduction to Solid-State Electronics

A design of semiconductor device and manufacturing technology is linked to the solid state physics principles in this course. Topics covered: The electronic structure of the atom, wave-particle duality of moving electrons. Schrodinger equation for periodic crystalline structure. Band theory of semiconductors. Brillouin zones. Statistics of electrons and holes. Kinetic effects: electrical conductivity, Hall effect, magnetoresistance. Optical properties: photoconductivity, light absorption and emission. Thermal properties including thermal conductivity, thermo EMF, recombination processes and role of defects. Prerequisite: 16.365 or Permission of Instructor.

16.428/16.528 Alternate Energy Sources Photovoltaics

PV conversion, cell efficiency, cell response, systems and applications. Wind Energy conversion systems: Wind and its characteristics; aerodynamic theory of windmills; wind turbines and generators; wind farms; siting of windmills. Other alternative energy sources: Tidal energy, wave energy, ocean thermal energy conversion, geothermal energy, solar thermal power, satellite power, biofuels. Energy storage: Batteries, fuel cells, hydro pump storage, flywheels, compressed air. Prerequisite: Permission of Instructor.

16.429/16.529 Electric Vehicle Technology

Electric vehicle VS internal combustion engine vehicle. Electric vehicle (EV) saves the environment. EV design, EV motors, EV batteries, EV battery chargers and charging algorithms, EV instrumentation and EV wiring diagram. Hybrid electric vehicles. Fuel cells. Fuel cell electric vehicles. The course includes independent work. Prerequisite: Permission of Instructor.

16.431/16.531 RF Design

Two-port network parameters, Smith chart applications for impedance matching, transmission line structures like stripline, microstrip line and coaxial line, filter designs for low-pass, high-pass and band-pass characteristics, amplifier design based on s-parameters, bias network designs, one port and two port oscillator circuits, noise in RF systems. Prerequisite: 16.360.

16.434 Active Network Theory

A study of active inductorless networks with emphasis on design and implementation. The course will cover the following subjects: approximation theory, the operational amplifier, the gyrator, the negative impedance converter, analysis of basic second-order active building blocks, the biquad building block, the state-variable filter, and the design of filters. The course includes a detailed design project. Prerequisite: 16.366.

16.435 Computational Electromagnetics

Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in electrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method. Prerequisite: 16.461.

16.439 Introduction to Communication Theory

An introduction to the study of time and frequency domain characteristics of signals arising in communications systems. Fourier analysis, discrete transform, correlation functions, power and energy density spectra. Time and frequency characteristics of thermal noise and random signals in data and noise communications. Spread spectrum concepts. Signal to noise ratio. Amplitude modulation, frequency modulation. Digital modulation, PAM, PCM, bandwidth control, time division multiplexing, transmission of binary data in noise. Prerequisite: 16.362.

16.440 Communication Systems

Analysis of the performance and operating characteristics of communication systems from the viewpoint of probability theory. Concentration on digital systems. Fundamentals of probability, expectation operator, Gaussian random variable. Markov processes, fundamentals of random processes. Discretization of analog signals. Fundamentals of information theory and coding. PN coding. Transmission of binary data in noise (matched filters). Optimal filters, tradeoffs of bandwidth power, and coding complexity in digital transmission. Applications. Hardware and/or simulation projects. Prerequisite: 16.362.

16.441 Introduction to Biosensors

This course introduces the theory and design of biosensors and their applications for pathology, pharmacogenetics, public health, food safety civil defense, and environmental monitoring. Optical, electrochemical and mechanical sensing techniques will be discussed. Prerequisite: 16.365

16.443/16.514 Power Systems Analysis

An intermediate course in analysis and operation of electrical power systems using mathematical techniques including applied calculus and matrix algebra. Topics include network reductions and representation of lines, generators, and transformers, network topology and transform methods. An introduction to protection and relaying is included. Symmetrical components will be introduced with application to polyphase systems. A design project is a major portion of the course. Prerequisite: 16.355.

16.444/16.525 Power Systems Distribution

An intermediate course in analysis and operation of electrical power distribution systems using applied calculus and matrix algebra. Topics include electrical loads characteristics, modeling , metering, customer billing, voltage regulation, voltage levels, and power factor correction. The design and operation of the power distribution system components will be introduced: distribution transformers, distribution substation, distribution networks, and distribution equipment. Prerequisite: 16.355.

16.445/16.565 Analog Devices & Techniques

A survey of analog devices and techniques, concentrating on operational amplifier design and applications. Monolithic operational amplifier design is studied both from the point of view of the op-amp designer whose goal is to optimize performance, as well as the application engineer who needs to understand the limitations of real op-amps, and to be able to interpret their specifications. Representative applications may include: simple amplifiers, differential and instrumentation amplifiers, summers, integrators, active filters, nonlinear circuits, and waveform generation circuits. A design project is required. Prerequisite: 16.366.

16.453/16.553 Software Engineering

Introduces software life cycle models, and engineering methods for software design and development. Design and implementation, testing, and maintenance of large software packages in a dynamic environment, and systematic approach to software design with emphasis on portability and ease of modification. Laboratories include a project where some of the software engineering methods (from modeling to testing) are applied in an engineering example. Prerequisites: 16.216 and 16.322.

16.450/16.550 Advanced Digital Systems Design

Design of logic machines, finite state machines, gate array designs, ALU and 4 bit CPU unit designs, microprogrammed systems. Hardware design of advanced digital circuits using XILINX. Application of probability and statistics for hardware performance and upgrading hardware systems. Laboratories incorporate specification, top down design, modeling, implementation and testing of actual advanced digital design systems hardware. Laboratories also include simulation of circuits using VHDL before actual hardware implementation and PLDs programming. Prerequisite: 16.265.

16.460/16.560 Medical Instrumentation

Analysis and design of Biomedical Instrumentation systems that acquire and process biophysical signals. properties of biopotential signals and electrodes; biopotential amplifiers and signal processing; basic sensors and principles; medical imaging systems; electrical safety. Prerequisites: 92.132 and 95.144.

16.461 Engineering Electromagnetics II

Continuation of Magnetostatics, Maxwell's Equations for Time-varying Fields, plane waves: time-harmonic fields, polarization, current flow in good conductors and skin effect, power density and Poynting vector, wave reflection and transmission; Snell's Law, fiber optics, Brewster angle, radiation and simple antennas, electromagnetic concepts involved in a topical technology in development. Prerequisites: 16.360.

16.462/16.506 Antenna Theory and Design

An introduction to properties of individual antennas and arrays of antennas. Retarded potentials, dipoles of arbitrary length, radiation pattern, gain, directivity, radiation resistance, will be covered. The loop antenna. Effects of the earth. Reciprocity, receiving antennas, effective length and area. Moment methods. Arrays: collinear, broadside, endfire. Array synthesis. Mutual coupling. Log-periodic and Yagi arrays. Radiation from apertures, including the waveguide horn antenna. Numerical software packages will be used throughout the course. A design project is required in the course. Prerequisite: 16.461.

16.465 Logic Design II

Error detection and correction codes. Map-entered variables. Minimization by Quine-McCluskey method. Multiple-output circuits. Timing hazards and hazard-free design. Analysis and Synthesis of synchronous and asynchronous sequential circuits. Races and essential hazards. Primitive flow tables. Flow table reductions and state assignments. Design using MSIs. Programmable logic devices: ROMs, PLAs, PALs, and PLSs. Design projects are included in the course. Prerequisite: 16.265.

6.466/16.566 Guided Wave Photonic Devices

Topics for the course will include guide-wave optics in 2D and 3D optical waveguides, and optical fiber together with concepts such as mode dispersion, and group velocity dispersion. Additional subjects include: Mode-coupling theory, directional coupler, and electro-optic effect and devices. The course will also cover optical amplifiers and DWDM technologies. Prerequisites: 16.360 and 16.461.

16.468/16.568 Electro-optics and Fiber Optics

Introduction to optoelectronics and laser safety; geometrical optics; waves and polarization; Fourier optics; coherence of light and holography; properties of optical fibers; acousto-optic and electro-optic modulation; elementary quantum concepts and photon emission processes; optical resonators; Fabry Perot etalon; laser theory and types; review of semiconductor lasers and detectors; nonlinear optics. Prerequisite: 16.360.

16.469/16.502 VLSI Design

Introduction to CMOS circuits including transmission gate, inverter, NAND, NOR gates, MUXes, latches and registers. MOS transistor theory including threshold voltage and design equations. CMOS inverter's DC and AC characteristics along with noise margins. Circuit characterization and performance estimation including resistance, capacitance, routing capacitance, multiple conductor capacitance, distributed RC capacitance, multiple conductor capacitance, distributed RC capacitance, switching characteristics incorporating analytic delay models, transistor sizing and power dissipation. CMOS circuit and logic design including fan-in, fan-out, gate delays, logic gate layout incorporating standard cell design, gate array layout, and single as well as two-phase clocking. CMOS test methodologies including stuck-at-0, stuck-at-1, fault models, fault coverage, ATPG, fault grading and simulation including scan-based and self test techniques with signature analysis. A project of modest complexity would be designed to be fabricated at MOSIS. Prerequisites: 16.265 and 16.365.

16.470/16.504 VLSI Fabrication

Fabrication of resistors, capacitors, p-n junction and Schottky Barrier diodes, BJT's and MOS devices and Integrated circuits. Topics include: silicon structure, wafer preparation, sequential techniques in micro-electronic processing, testing and packaging, yield and clean room environments. MOS structures, crystal defects, Fick's laws of diffusion; oxidation of silicon, photolithography including photoresist, development and stripping. Metallization for conductors, Ion implantation for depletion mode and CMOS transistors for better yield speed, low power dissipation and reliability. Students will fabricate circuits using the DSIPL Laboratory. Prerequisite: 16.365.

16.473/16.515 Power Electronics

A one-semester course with emphasis on the engineering design and performance analysis of power electronics converters. Topics include: power electronics devices (power MOSFETs, power transistors, diodes, silicon controlled rectifiers SCRs, TRIACs, DIACs and Power Darlington Transistors), rectifiers, inverters, ac voltage controllers, dc choppers, cycloconverters, and power supplies. The course includes a project, which requires that the student design and build one of the power electronics converters. A demonstrative laboratory to expose the students to all kinds of projects is part of the course. Prerequisites: 16.355 and 16.366.

16.474/16.576 Principles of Solid-State Devices

Principles of Solid State Devices: Crystal properties and growth of semi-conductors, atoms and electrons, Bohr's model, quantum mechanics, bonding forces and energy bands in solids, charge carriers in semiconductors, drift of carriers in electric and magnetic fields, carrier lifetime and photoconductivity, junctions, forward and reverse bias, reverse bias breakdown (Zener effect), tunnel diodes, photodiodes, LED, bipolar junction transistors, field effect transistors. Prerequisite: 16.365.

16.475 Automated Test Systems

A design-oriented introduction to the techniques of modern automatic test systems, covering both hardware and software. Topics include: automated testing in engineering and manufacturing; the IEEE -488 instrument bus; programmable test equipment; the device under test interface; modular software development; and human engineering and ethical considerations. The course includes a project in which students develop a complete automated test system for some real device. Student designs are implemented in the ECE Department’s Automated Test System Laboratory. During the project students maintain project schedules and conduct design reviews to critique each other's designs. Completed projects are demonstrated and thoroughly documented. Prerequisite: 16.366.

16.476 Photovoltaics

An introductory course in photovoltaics concentrating on solar cells for energy conversion. Solar radiation and conversion efficiency. Photovoltaic materials, energy bands and carrier transport, semiconductors and conductors. P-n junctions, depletion region, current voltage characteristics, efficiency. Heterojunctions and thin film solar cells. Balance of system components for a photovoltaic system including electrical storage. Barrier to extensive use of photovoltaic systems. Prerequisite: 92.132 or Permission of Instructor.

16.480/16.552 Microprocessors II and Embedded Systems

This course provides a continuation of the study of microprocessors begun in 16.317. Topics include CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, bus arbitration techniques, serial I/O devices, DMA, interrupt control devices. Focus will be placed on the design, construction, and testing of dedicated microprocessor systems (static and real-time). Hardware limitations of the single-chip system will be investigated along with microcontrollers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, and design methods and testing of embedded systems. Laboratories directly related to microprocessor functions and its interfaces. Prerequisites: 16.311, 16.317, and 16.365.

16.481/16.573 Operating Systems and Kernel Design

Covers the components, design, implementation, and internal operations of computer operating systems. Topics include basic structure of operating systems, Kernel, user interface, I/O device management, device drivers, process environment, concurrent processes and synchronization, inter-process communication, process scheduling, memory management, deadlock management and resolution, and file system structures. laboratories include examples of components design of a real operating systems. Prerequisite: 16.216 or Programming Skills

16.482/16.561 Computer Architecture and Design

Structure of computers, past and present, including: first, second, third and fourth generation. Combinational and sequential circuits. Programmable logic arrays. Processor design including: information formats, instruction set architecture, integer and real arithmetic, design of the CPU data path, hardwired and micro-programmed control, pipelined and superscalar architectures, Memory hierarchy including cache and virtual memory. Input-output systems, communication and bus control. Multiple CPU systems. Prerequisites: 16.265 and 16.317.

16.483/16.583 Network Design: Principles, Protocols and Applications

Covers design and implementation of network software that transforms raw hardware into a richly functional communication system. Real networks (such as the Internet, ATM, Ethernet, Token Ring) will be used as examples. Presents the different harmonizing functions needed for the interconnection of many heterogeneous computer networks. Internet protocols, such as UDP, TCP, IP, ARP, BGP and IGMP, are used as examples to demonstrate how internetworking is realized. Applications such as electronic mail and the WWW are studied. Topics include: inter-network architectures, high speed network service protocol implementation, addressing and address mapping, intra- and inter-domain routing, multicasting, mobility, auto-configuration, resource allocation, transport protocols, naming, client-server model, network programming interfaces (e.g., sockets, RMI, RPC, CORBA), secure transport protocols for high-speed networks and applications. Prerequisite: 16.216 or Programming Skills.

16.484/16.581 Computer Vision and Digital Image Processing

Introduces the principles and the fundamental techniques for Image Processing and Computer Vision. Topics include programming aspects of vision, image formation and representation, multi-scale analysis, boundary detection, texture analysis, shape from shading, object modeling, stereo-vision, motion and optical flow, shape description and objects recognition (classification), and hardware design of video cards. AI techniques for Computer Vision are also covered. Laboratories include real applications from industry and the latest research areas. Prerequisites: 16.216 or 16.322, 16.362 or Permission of Instructor.

16.490/16.590 Fiber Optic Communications

Optical fiber; waveguide modes, multimode vs. single mode; bandwidth and data rates; fiber losses; splices, couplers, connectors, taps and gratings; optical transmitters; optical receivers; high speed optoelectronic devices; optical link design; broadband switching; single wavelength systems; wavelength division multiplexing; fiber amplifiers. Prerequisites: 16.360 and 16.362 or Permission of Instructor.

16.491 Industrial Experience

This three credit course is for co-op or industrial experience. The co-op internship should be for at least 500 hours in order to be eligible for credit. Only 3 credits may be used toward the BS Eng in CpE or EE degree. Registration for this course is conditional on the approval of the Department Co-op coordinator. A grade of Satisfactory or Unsatisfactory is given. Prerequisite: Permission of Instructor.

16.499 Capstone Project

The purpose of the CAPSTONE Project is to provide the student with a design experience which resembles entry level engineering assignments. It is expected that the project encompass a minimum of three technical areas within the CpE or EE discipline, and include some aspects of each step in the development of a marketable product i.e. Research, Design and Development, Manufacture, Marketing and Service. A formal technical report must be submitted prior to the submission of a course grade. Prerequisites: 16.399 and 16.400.

Graduate Courses

Courses with asterisk (*) are offered based on demand and availability of departmental resources.

16.501 Discrete Algebra*

A comprehensive course addressing the diversity of discrete algebraic systems needed in digital system synthesis and analysis. Logic Sets and Functions. Introduction to algorithms including recursive algorithms, integers, elementary matrix theory. Mathematical reasoning and proofs, proof by induction. Basics of counting, combinatorics, generalized permutations and combinations, elements of discrete probability. Recurrence relations and solution of recurrence relations, generating functions. Relations and their properties, equivalence relations, partial and total orderings. Graph theory, Euler and Hamilton graphs and paths, shortest path algorithm, planar graphs. Trees, spanning trees and minimum spanning trees, binary trees. Prerequisite: 16.362 or equivalent.

16.502 VLSI Design

Introduction to CMOS circuits including transmission gate, inverter, NAND, NOR gates, MUXes, latches and registers. MOS transistor theory including threshold voltage and design equations. CMOS inverter's DC and AC characteristics along with noise margins. Circuit characterization and performance estimation including resistance, capacitance, routing capacitance, multiple conductor capacitance, distributed RC capacitance, multiple conductor capacitance, distributed RC capacitance, switching characteristics incorporating analytic delay models, transistor sizing and power dissipation. CMOS circuit and logic design including fan-in, fan-out, gate delays, logic gate layout incorporating standard cell design, gate array layout, and single as well as two-phase clocking. CMOS test methodologies including stuck-at-0, stuck-at-1, fault models, fault coverage, ATPG, fault grading and simulation including scan-based and self test techniques with signature analysis. A project of modest complexity would be designed to be fabricated at MOSIS. Prerequisites: 16.265 and 16.365.

16.504 VLSI Fabrication

Fabrication of resistors, capacitors, p-n junction and Schottky Barrier diodes, BJT's and MOS devices and Integrated circuits. Topics include: silicon structure, wafer preparation, sequential techniques in micro-electronic processing, testing and packaging, yield and clean room environments. MOS structures, crystal defects, Fick's laws of diffusion; oxidation of silicon, photolithography including photoresist, development and stripping. Metallization for conductors, Ion implantation for depletion mode and CMOS transistors for better yield speed, low power dissipation and reliability. Students will fabricate circuits using the DSIPL Laboratory. Prerequisite: 16.365.

16.505 Microwave Electronics
Review of p-n junction theory, depletion layer width and junction capacitance, Schottky barrier diodes, pin diodes and applications in switches and phase shifters, varactors and step recovery diodes, tunnel diodes and circuits, Gunn devices and circuits, avalanche diodes, IMPATT, TRAPATT and BARRITT diodes, microwave bipolar junction transistors (BJT) and field effect transistors (FET), small signal amplifier design, new devices like HEMT and Si-Ge devices, traveling wave tubes and klystrons. Prerequisite: 16.365.

16.506 Antenna Theory and Design
An introduction to properties of individual antennas and arrays of antennas. Retarded potentials, dipoles of arbitrary length, radiation pattern, gain, directivity, radiation resistance. The loop antenna. Effects of the earth. Reciprocity, receiving antennas, effective length and area. Moment methods. Arrays: collinear, broadside, endfire. Array synthesis. Mutual coupling. Log-periodic and Yagi arrays. Radiation from apertures: the waveguide horn antenna, parabolic dish. Antenna noise temperature. Numerical software packages. Prerequisite: 16.461.

16.507 Electromagnetic Waves and Materials
This is a graduate core course, which serves the needs of students who study electromagnetics as a basis for a number of electromagnetic technologies including photonic technologies. Study of Electromagnetic Wave Interactions with Bounded Simple Media: transmission lines, Green's function, fibers, conducting waveguides and cavity resonators, Plane waves in Complex Electromagnetic Materials: plasmas, dispersive dielectrics, mixing formulas, optical waves in metals, super conductors, chiral media, crystals, magnetized plasma and time-varying media, layered and periodic media. Prerequisite: 16.461.

16.508 Quantum Electronics for Engineers
Introduction to the fundamental postulates of quantum theory: Planck's quantization hypothesis; wave-particle duality; time-dependent and time-independent Schrodinger's Equation; simple quantum mechanical systems. Radiation and quanta; quantization of the radiation field and cavity modes; absorption and emission of radiation; coherence functions; coherent states; importance of quantum fluctuations and quantum nature of light; laser amplifiers and amplifier nonlinearity; electromagnetics and quantum theory of laser oscillators; photons in semiconductors; semiconductor photon sources and detectors. Prerequisites: 16.363 and 16.461.

16.509 Linear Systems Analysis
Correlation and Circular convolutions. Concepts of orthogonality and Gramm-Schmidt orthogonalization procedure. Fourier series and Fourier transforms (FT): convergence properties; applications to linear systems including modulation, sampling and filtering. Hilbert transforms (HT) and analytic signals. Bilateral Laplace transforms (LT): convergence properties. Contour integration methods applied to FT, HT and LT. Discrete-time Fourier series and Fourier transforms including complex convolution: applications to linear systems. Discrete Fourier transforms and Fast Fourier algorithm. Z-transforms: convergence properties, solution of difference equations, application to linear systems. Correlation. Prerequisite: 16.362.

16.510 Digital Signal Processing
Review of Z-Transforms and solutions of linear difference equations. Digital filter structures, parameter quantization effects and design techniques. FFT and Chirp Z-Transform methods. Discrete Hilbert Transforms, minimum-phase sequences and their application to Homomorphic Signal Processing and calculation of Complex Cepstrum. Prerequisite: 16.362, 16.363 preferred.

16.511 Medical Imaging Diagnosis
This course covers the physics and electrical engineering aspects of how signals are acquired from which images will be formed, and the principal methods by which the signals are processed to form useful medical diagnostic images. Modalities studied include: x-rays, ultrasound, computed tomography, and magnetic resonance imaging. The principles of signal processing via Fourier transform will be reviewed. Noise and other artifacts that degrade the medical diagnostic of images are considered. MATLAB is heavily used in simulation and verification. Prerequisite: 16.362.

16.512 Electronic Materials*
Introduction to types of electronic materials, including semiconducting, optical, superconducting, and magnetic materials. Material quality vs. device performance. Defects such as point defects, dislocations, phase boundaries, and second phases, and their electronic effects. The phase rule, phase diagrams, and thermodynamics. Introduction to crystallography. Physical basis for quantum behavior in solid state devices. Bulk and thin film materials preparation - starting materials, crystal growth, and control requirements. Each student will undertake an individual project reviewing preparation methods for a material of industrial or research importance. Prerequisite: Permission of Instructor

16.513 Control Systems
System representations, state variables, transfer functions, controllability and observability, phase variables, canonical variables, representation of nonlinear systems, Lagrange's equations, generalized co-ordinates, time response of linear systems, state transition matrix, Sylvester's expansion theorem, stability and state function of Liapunov, transient behavior estimation, optimal control, state function of Pontryagin, variational calculus, Hamilton Jacobi method, matrix Riccati equation, linear system synthesis. Prerequisite: 16.413.

16.514 Power Systems Analysis*
An intermediate course in analysis and operation of electrical power systems using mathematical techniques including applied calculus and matrix algebra. Topics include network reductions and representation of lines, generators, and transformers, network topology and transform methods. An introduction to protection and relaying is included. Symmetrical components will be introduced with application to polyphase systems. Prerequisite: 16.355.

16.515 Power Electronics
Design and performance analysis of rectifiers, inverters, DC chopper, AC voltage controllers, cycloconverters, and power supplies. The course includes a design project in the laboratory. Prerequisites: 16.355 and 16.366.

16.516 Advanced Machine Theory*
Electromechanical energy conversion. Reference-frame theory. Dynamics of DC, induction, and synchronous machines. Unbalanced operation of induction and synchronous machines. Prerequisite: 16.355.

16.517 MMIC Design and Fabrication*
The goal of MMIC design and fabrication is to prepare students for designing integrated circuits operating at GHz frequencies. The design is based on scattering parameters of the MESFETs and PHEMTs. The real challenge in this case is to relate S11, S12, S21 and S22 with the fabrication technology parameters such as channel conductance, transconductance and threshold voltages etc. This course not only covers RF design techniques but also the manufacturability and testability of the circuits at GHz frequencies, including packaging techniques. Prerequisite: 16.360 or Permission of Instructor.

16.519 Engineering of Submicron Machines
Recently fabrication of Very Large Scale Integrated circuits has spun-off a new technology of micro-machines (MEMS) and sensors on a semiconductor wafer. These new devices are ideally located next to a microprocessor on the same wafer or a separate chip. The data transfer to and from a miniature machine, sensor or transducer is processed and controlled on site. Topics include design of mechanical, electrical and biological transducers; properties of electronic materials; pattern generation on a semiconductor wafer; interface of a micromachine and processor; applications and markets for submicron machines; their role in nanotechnology. Prerequisite: 16.365 or Permission of Instructor.

16.520 Computer-Aided Engineering Analysis
Taylor series. Number systems and error. Difference and summation calculus. Interpolation. Definite integrals. Differential equation modeling and stability; Predictor-Corrector and Runge-Kutta methods. Orthogonal polynomials. Discrete transforms. Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, quasi-Newton and conjugate gradient methods of optimization. Prerequisites: 16.364 and 92.234.

16.521 Real-Time Digital Signal Processing
This course provides an introduction to real-time digital signal processing techniques using ADSP-21161, 21262, BF561, TS201S floating/fixed point processors. This is a practical course with 'hands on' training using the latest software development tools. First the core elements of the processor (computational units, data address generators, program sequencer) are examined in detail along with the relevant assembly code instructions. Internal and external memory configuration is also discussed. Advanced instructions are presented with a follow on lab on code optimization. The I/O peripherals (SPORTS, link ports, external port) are discussed in detail along with DMA operation between these peripherals and internal memory. Throughout the course, the various aspects of the software development process using the latest tools are discussed including setting up and building projects, assembly language programming, code debugging, simulation, tool support for code overlays and shared memory, and 'C' programming support. Hardware development tools, such as evaluation boards and ICE's are introduced with a follow on hardware/software lab where the student develops a simple interrupt driven application for a hardware target. Prerequisites: 16.362 and C or Assembly programming knowledge.

16.522 Data Structures*
Character strings, character substring searches; lists, their storage structures and uses; trees, tree searches, and storage concepts; compiling, Polish strings, translating from infix to postfix and prefix, conversion to machine code. Prerequisites: 16.216 and 16.322.

16.523 Introduction to Solid-State Electronics
In this course the design of semiconductor devices and manufacturing technology is linked to the conventional and quantum transport of electrons in semiconductors. Topics covered: The electronic structure of the atom, wave-particle duality of moving electrons. Schrodinger equation for periodic crystalline structure. Band theory of semiconductors. E-k diagrams and Brillouin zones for quantum wires and quantum dots. Statistics of electrons and holes. Kinetic effects: electrical conductivity, Hall effect, magnetoresistance. Optical properties: photoconductivity, light absorption and emission. Thermal properties including thermal conductivity, recombination processes and role of defects. Prerequisite: 16.365 or Permission of Instructor.

16.524 Programming Languages*
Syntax and semantics of programming languages. Fundamental concepts of control structures, modularity, scope of identifiers, recursion, and data structures. Examples of real programming languages such as FORTRAN, Pascal, LISP, APL, C++, and ADA. Prerequisite: FORTRAN, Pascal, or C.

16.525 Power Systems Distribution
An intermediate course in analysis and operation of electrical power distribution systems using applied calculus and matrix algebra. Topics include electrical loads characteristics, modeling , metering, customer billing, voltage regulation, voltage levels, and power factor correction. The design and operation of the power distribution system components will be introduced: distribution transformers, distribution substation, distribution networks, and distribution equipment. Prerequisite: 16.355.

16.527 Advanced VLSI Design Techniques
This course builds on the previous experience with Cadence design tools and covers advanced VLSI design techniques for low power circuits. Topics covered include aspects of the design of low voltage and low power circuits including process technology, device modeling, CMOS circuit design, memory circuits and subsystem design. This will be a research-oriented course based on team projects. Prerequisite:16.469 or 16.502

16.528 Alternate Energy Sources
Photovoltaics: PV conversion, cell efficiency, cell response, systems and applications. Wind Energy conversion systems: Wind and its characteristics; aerodynamic theory of windmills; wind turbines and generators; wind farms; siting of windmills. Other alternative energy sources: Tidal energy, wave energy, ocean thermal energy conversion, geothermal energy, solar thermal power, satellite power, biofuels. Energy storage: Batteries, fuel cells, hydro pump storage, flywheels, compressed air. Course is also listed as 24.528. Prerequisite: Permission of Instructor.

16.529 Electric Vehicle Technology
Electric vehicle VS internal combustion engine vehicle. Electric vehicle (EV) saves the environment. EV design, EV motors, EV batteries, EV battery chargers and charging algorithms, EV instrumentation and EV wiring diagram. Hybrid electric vehicles. Fuel cells. Fuel cell electric vehicles. The course includes independent work. Prerequisite: Permission of Instructor.

16.531 RF Design
Two-port network parameters, Smith chart applications for impedance matching, transmission line structures like stripline, microstrip line and coaxial line, filter designs for low-pass, high-pass and band-pass characteristics, amplifier design based on s-parameters, bias network designs, one port and two port oscillator circuits, noise in RF systems. Prerequisite: 16.360.

16.532 Computational Electromagnetics
Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in electrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method. Prerequisite: 16.461.

16.533 Microwave Engineering
An introductory course in the analysis and design of passive microwave circuits beginning with a review of time-varying electromagnetic field concepts and transmission lines. Smith Chart problems; single and double stub matching; impedance transformer design; maximally flat and Chebyshev transformers; microstrip transmission lines, slot lines, coplanar lines; rectangular and circular waveguides; waveguide windows and their use in impedance matching; design of directional couplers; features of weak and strong couplings; microwave filter design; characteristics of low-pass, high-pass, band-pass, band-stop filter designs; two -port network representation of junctions; Z and Y parameters, ABCD parameters, scattering matrix; microwave measurements; measurement of VSWR, complex impedance, dielectric constant, attenuation, and power. A design project constitutes a major part of the course. Prerequisite: 16.461.

16.534 Microwave Laboratory
This laboratory course introduces the students to the measurement of various quantities at microwave frequencies. The experiments include measurement of (i) frequency and wavelength (ii) complex impedance (iii) dielectric constant (iv) attenuation (v) insertion loss and isolation of PIN diode switches (vi) radiation pattern of horn antennas (vii) scattering parameters of networks using network analyzer (viii) power output from Gunn and IMPATT diodes. Prerequisite: 16.360 or permission of instructor.

16.541 Introduction to Biosensors
This course introduces the theory and design of biosensors and their applications for pathology, pharmacogenetics, public health, food safety civil defense, and environmental monitoring. Optical, electrochemical and mechanical sensing techniques will be discussed. Prerequisite: 16.365.

16.543 Theory of Communication
Information transmission and deterministic signals in time and frequency domains. Relationship between correlation and power or energy spectra. Statistical properties of noise. Spectral analysis and design of AM, FM and pulse modulation systems, continuous and discrete. AM, FM, and various pulse modulation methods, in the presence of noise. Digital modulation and demodulation technique. Prerequisites: 16.362 and 16.363 or 16.584 or equivalent.

16.546 Computer Telecommunications
An in depth survey of the elements of the modern computer based telecommunications system. Discussion of media used to transport voice and data traffic including twisted pair, baseband and broadband coaxial cable, fiber optic systems and wireless systems. Techniques for sending data over the media are presented including modems, baseband encoding, modulation and specific cases such as DSL, cable modems, telephone modems. Architecture and functionality of telephone system that serves as backbone for moving data, including multiplexing, switching, ATM, ISDN, SONET. Layered software architectures are discussed including TCP/IP protocol stack and the ISO/OSI seven layer stacks are examined in depth from data link protocols to transport protocols. LAN and WAN architectures including media access control (MAC) techniques are discussed for Ethernet, token ring and wireless LAN applications. Internetworking protocols and the role of repeaters, routers, and bridges. Voice over IP and state of the art applications. Prerequisites: 16.362 and 16.363 or 16.584 or Permission of Instructor.

16.548 Coding and Information Theory
Probabilistic measure of information. Introduction to compression algorithms including L -Z, MPEG, JPEG, and Huffman encoding. Determination of the information handling capacity of communication channels and fundamental coding theorems including Shannon's first and second channel coding theorems. Introduction to error correcting codes including block codes and convolutional coding and decoding using the Viterbi algorithm. Applications of information theory and coding to advanced coding modulation such as Trellis code Modulation (TCM) and turbo modulation. Prerequisites: 16.362, 16.363, 16.543, 16.584 or equivalent is desirable, programming in C, VB, or Matlab, or Permission of Instructor.

16.550 Advanced Digital Systems Design
Design of logic machines, finite state machines, gate array designs, ALU and 4 bit CPU unit designs, microprogrammed systems. Hardware design of advanced digital circuits using XILINX. Application of probability and statistics for hardware performance and upgrading hardware systems. Laboratories incorporate specification, top down design, modeling, implementation and testing of actual advanced digital design systems hardware. Laboratories also include simulation of circuits using VHDL before actual hardware implementation and PLDs programming. Prerequisite: 16.265.

16.552 Microprocessors Systems II and Embedded Systems
This course provides a continuation of the study of microprocessors begun in 16.317. Topics include CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, bus arbitration techniques, serial I/O devices, DMA, interrupt control devices. Focus will be placed on the design, construction, and testing of dedicated microprocessor systems (static and real-time). Hardware limitations of the single-chip system will be investigated along with microcontrollers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, and design methods and testing of embedded systems. Laboratories directly related to microprocessor functions and its interfaces. Prerequisites: 16.311, 16.317, and 16.365.

16.553 Software Engineering
Introduces software life cycle models, and engineering methods for software design and development. Design and implementation, testing, and maintenance of large software packages in a dynamic environment, and systematic approach to software design with emphasis on portability and ease of modification. Laboratories include a project where some of the software engineering methods (from modeling to testing) are applied in an engineering example. Prerequisites: 16.216 and 16.322.

16.554 Voice Recognition Processing and Computer Sound Drivers*
Introduces voice recognition processing, linear predictive modeling techniques, voice compression methods. Digital voice algorithms and lattice/ladder digital filters in voice models. Topics cover musical instruments using computationally efficient algorithms, microphone arrays for beam-forming, real-time voice processing, 16 bit and higher sound drivers. Laboratories include implementation of voice recognition algorithms, sound drivers and applications. Prerequisite: 16.482.

16.556 Robotics
Introduces the basic aspects of mobile robotics programming, starting at low-level PID control and behavioral robot control. Covers the analysis, design, modeling and application of robotic manipulators. Forward and inverse kinematics and dynamics, motion and trajectory control and planning are also covered. Laboratories include design, analysis and simulation of real life industrial robots. Prerequisite: Permission of Instructor.

16.557 Object Oriented Design*
Introduces the fundamentals of the object-oriented paradigm, such as classes, objects, the association relationship, the uses relationship, the containment relationship and the inheritance relationship. Studies the relationship between methodologies based on the data driven approach and the behavioral approach. Covers object-oriented design patterns and their relationship to design heuristics. Laboratories includes generic programming, programming by contracts, programming with meta-classes, and the concrete realizations of components in some industrial standards (e.g. Java Swing, Entreprise JavaBeans, JINI, etc.). Prerequisite: 16.322.

16.558 World Wide Web Programming*
Covers design and development of WWW pages, images, dialogue boxes and tables, using HTML, Java Scripts, image maps and tables, and Java Swing programming principles and techniques. Laboratories include usage of Java Database Connectivity, Servelets, Remote Method Invocation (RMI), Java Networking, and Multimedia, all based on WWW. Prerequisite: 16.322.

16.560 Biomedical Instrumentation
Analysis and design of Biomedical Instrumentation systems that acquire and process biophysical signals. properties of biopotential signals and electrodes; biopotential amplifiers and signal processing; basic sensors and principles; medical imaging systems; electrical safety. Prerequisites: 92.132 and 95.144.

16.561 Computer Architecture and Design
Structure of computers, past and present, including: first, second, third and fourth generation. Combinational and sequential circuits. Programmable logic arrays. Processor design including: information formats, instruction set architecture, integer and real arithmetic, design of the CPU data path, hardwired and micro-programmed control, pipelined and superscalar architectures, Memory hierarchy including cache and virtual memory. Input-output systems, communication and bus control. Multiple CPU systems. Prerequisites: 16.265 and 16.317.

16.562 VHDL/Verilog Synthesis and Design
Circuit and system representations including behavioral, structural, and physical descriptions using HDL. Modeling of short and narrow MOS transistors for submission applications. Overview of CMOS technology including oxidation, epitaxy, deposition, ion implantation and diffusion essential for multilayer vias. 2-0 and 4-0 memory structures, I/O structures and PADS. System design including structural, hierarchy, regularity, modularity and programmable gate arrays. RTL synthesis, layout and placement, design capture tools, including schematic, netlist, verification and simulation. Fast adders, subtractors, multipliers, dividers, ALUs, CPUs, RAMs, ROMs, row/column decoders, FIFOS, and FSMs with detailed examples. A RISC microcontroller, pipeline architecture including logic blocks, data paths, floor planning, functional verification and testing. Layout and simulation of chips as well as of PCs based on VHDL, Verilog, and HILO will be encouraged. Prerequisite: 16.265 and 16.365, or Permission of Instructor.

16.563 System Programming*
System programming structures with emphasis on re-entrant programming and pure procedures. Nested calls, push-down stacks and queues. Re-entrant interrupt programming, activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, processes and assemblers. Prerequisite: 16.317.

16.565 Analog Devices and Techniques
A survey of analog devices and techniques, concentrating on operational amplifier design and applications. Operational amplifier design is studied to reveal the limitations of real op-amps, and to develop a basis for interpreting their specifications. Representative applications are covered, including: simple amplifiers, differential and instrumentation amplifiers, summers, integrators, active filters, nonlinear circuits, and waveform gene-ration circuits. A design project is required. Prerequisite: 16.366.

16.568 Electro Optics and Integrated Optics
Introduction to optoelectronics and laser safety; geometrical optics; waves and polarization; Fourier optics; coherence of light and holography; properties of optical fibers; acousto-optic and electro-optic modulation; elementary quantum concepts and photon emission processes; optical resonators; Fabry Perot etalon; laser theory and types; review of semiconductor lasers and detectors; nonlinear optics. Prerequisite: 16.360.

16.571 Radar Systems
Introduction to both pulsed and C. W. radar systems. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Detection of radar echoes in noise. Range and Doppler resolution. Basics of Tracking systems. A final project is required in the course. Prerequisites: 16.362, 16.363, and 16.461 or Permission of Instructor.

16.572 Embedded Real-Time Systems
Design of embedded real-time computer systems. Polled vs. interrupt-driven input/output. Writing interrupt handlers. Types of real-time systems, including foreground/background, non-preemptive multitasking, and priority-based pre-emptive multitasking systems. Soft vs. hard real-time systems. Task scheduling algorithms and deterministic behavior. Task synchronization and inter-task communication including: semaphores, mutexes, mailboxes, and message queues. Deterministic memory management schemes. Application and design of a real-time kernel. A project is required. Prerequisites: 16.216, 16.317, and 16.322 or Permission of Instructor.

16.573 Operating Systems and Kernel Design
Covers the components, design, implementation, and internal operations of computer operating systems. Topics include basic structure of operating systems, Kernel, user interface, I/O device management, device drivers, process environment, concurrent processes and synchronization, inter-process communication, process scheduling, memory management, deadlock management and resolution, and file system structures. laboratories include examples of components design of a real operating systems. Prerequisite: 16.216 or Programming Skills.

16.574 Advanced Logic Design
Error detection and correction codes. Minimization of switching functions by Quine-McCluskey (tabular) methods. Minimization of multiple-output circuits. Reed-Muller polynomials and exclusive-OR circuits. Transient analysis of hazards. Hazard-free design. Special properties of switching algebra. Programmable logic devices. Analysis and synthesis of fundamental-mode and pulsed-mode sequential circuits. Test sets and design for testability. Prerequisite: 16.265.

16.575 Field Programmable Gate Array Logic Design Techniques
This course presents advanced logic design techniques using FPGA's, PLD's, PAL's, and other forms of reconfigurable logic. Architectural descriptions and design flow using Verilog and VHDL will be covered as well as rapid prototyping techniques, ASIC conversions, in-system programmability, and case studies highlighting the tradeoffs involved in designing digital systems with programmable devices. Prerequisite: 16.265 or Equivalent.

16.576 Principles of Solid-State Devices
Introduces the principles of Solid State Devices. Crystal properties and growth of semiconductors, atoms and electrons, Bohr's model, quantum mechanics, bonding forces and energy bands in solids, charge carriers in semiconductors, drift of carriers in electric and magnetic fields, carrier lifetime and photoconductivity, junctions, forward and reverse bias, reverse bias breakdown (Zener effect), tunnel diodes, photodiodes, LED, bipolar junction transistors, field effect transistors. A design project is included in the course. Prerequisite: 16.365.

16.577 Verification of Very Large Digital Designs
The increasing complexity of digital designs coupled with the requirement for first pass success creates a need for an engineered approach to verification. This course defines the goals for verification, presents techniques and applications, and develops a framework for managing the verification process from concept to reality. Prerequisite: 16.574 or Equivalent.

16.581 Computer Vision and Digital Image Processing
Introduces the principles and the fundamental techniques for Image Processing and Computer Vision. Topics include programming aspects of vision, image formation and representation, multi-scale analysis, boundary detection, texture analysis, shape from shading, object modeling, stereo-vision, motion and optical flow, shape description and objects recognition (classification), and hardware design of video cards. AI techniques for Computer Vision are also covered. Laboratories include real applications from industry and the latest research areas. Prerequisites: 16.216 or 16.322, 16.362 or Permission of Instructor.

16.582 Wireless Communications
Cellular systems and design principles, co-channel and adjacent channel interference, mobile radio propagation and determination of large scale path loss, propagation mechanisms like reflection, diffraction and scattering, outdoor propagation models, Okumura and Hata models, small scale fading and multipath, Doppler shift and effects, statistical models for multipath, digital modulation techniques QPSK, DPSK, GMSK, multiple access techniques, TDMA, FDMA, CDMA, spread spectrum techniques, frequency hopped systems, wireless systems and worldwide standards. Prerequisite: 16.360.

16.583 Network Design: Principles, Protocols and Applications
Covers design and implementation of network software that transforms raw hardware into a richly functional communication system. Real networks (such as the Internet, ATM, Ethernet, Token Ring) will be used as examples. Presents the different harmonizing functions needed for the interconnection of many heterogeneous computer networks. Internet protocols, such as UDP, TCP, IP, ARP, BGP and IGMP, are used as examples to demonstrate how internetworking is realized. Applications such as electronic mail and the WWW are studied. Topics include: inter-network architectures, high speed network service protocol implementation, addressing and address mapping, intra- and inter-domain routing, multicasting, mobility, auto-configuration, resource allocation, transport protocols, naming, client-server model, network programming interfaces (e.g., sockets, RMI, RPC, CORBA), secure transport protocols for high-speed networks and applications. Prerequisite: 16.216 or Programming Skills.

16.584 Probability and Random Processes
Sample space, Field and Probability Measure. Axiomatic definition of Probability. Bayes' theorem. Repeated trials. Continuous and discrete random variables and their probability distribution and density functions. Functions of random variables and their distribution and density functions. Expectation, variance and higher order moments. Characteristic and generating functions. Vector formulation of random variables and their parameters. Mean square estimation and orthogonality principle. Criteria for estimators. Introduction to random processes: distribution and density functions; Ensemble and time averages; correlation functions and spectral densities. Classification of random processes. Random processes through linear systems. Weiner filters and Kalman filters. Simulation of random variables and hypothesis tests. Prerequisite: 16.362.

16.586 Stochastic Modeling in Telecommunications
Discrete and Continuous time Markov Chains; Chapman-Kolmogorov Equation. Kolmogorov Forward and Backward equations; Poisson, Birth, Birth-Death processes. Diffusion processes; Wiener Process; Renewal processes. Fluid approximations; Introduction to rare event analysis and large deviations; AR and ARMA time series models and applications in basic telecommunications systems including traffic forecasting, and queue modeling: Prerequisite: 16.584 or equivalent.

16.590 Fiber Optic Communications
Optical fiber; waveguide modes, multimode vs. single mode; bandwidth and data rates; fiber losses; splices, couplers, connectors, taps and gratings; optical transmitters; optical receivers; high speed optoelectronic devices; optical link design; broadband switching; single wavelength systems; wavelength division multiplexing; fiber amplifiers. Prerequisites: 16.360 and 16.362 or Permission of Instructor.

16.593 Industrial Experience
This no credit course is for co-op or industrial experience.

16.594 Industrial Experience
This no credit course is for co-op or industrial experience.

16.595 Solid-State Electronics
Topics included are physical limits of microminiaturization, metal semiconductor junctions, p-n junctions diodes, (rectifiers, varactors, tunnel diodes and photodetectors and solar cells); bipolar junction transistors, field effect transistors (junction FET, MESFET, MOSFET); heterojunction devices and high speed devices; quantum dots, wires and two dimensional quantum well devices, light emitting devices; flat panels, liquid crystals and hot electron emitters. Prerequisite: 16.523 or Permission of Instructor.

16.602 VHDL/Verilog Synthesis and Design
This course is changed to 16.562.

16.606 High Speed Semiconductor Devices*
Materials technologies for high speed devices, ideal semiconductors and fabrication technologies; electric field and current transport, electrons in strong electric field, tunneling, space charge limited current, hot electrons, shape of field in channel; device building blocks, symmetric n-i-n structure, inversion layers, quantum wells. The following devices will be described: submicron MOSFETs, SOI-MOSFETs, short channel MESFETs, the permeable base transistor, heterojunction transistors, single electron transistor and high speed photonic devices. Prerequisite: Permission of Instructor.

16.607 Electromagnetics of Complex Media
Continuation of 16.507 dealing with more current research topics on complex materials. Special emphasis on time-varying media. Prerequisite: 16.507 or equivalent.

16.612 Converged Voice and Data Network
Covers the tecxhnologies and protocols used to transport voice and data traffic over a common communication network, with emphasis on voice over IP (VoIP). The specific topics covered include voice communication network fundamentals, data networking fundamentals, voice packet processing, voice over packet networking, ITU-T VoIP arcxhitecture, IETF VoIP architecture, VoIP over WLAN,m access networks for converged services: xDSL and HFC networks, and IP TV service. Pre-Requisite: 16.546 or Permission of Instructor.

16.613 Nonlinear Systems Analysis*
Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, Quasi-Newton and conjugate gradient methods of constrained optimization. Approximation methods for ordinary and partial non-linear differential equations. Stability and the methods of Lyapunov. Prerequisite: 16.520

16.614 Optimal Control Theory*
Deterministic optimal control systems. Performance measures for optimal systems. Dynamic programming and related computer techniques. Discrete linear regulator. The Hamilton-Jacobi-Bellman equation. Continuous linear regulator. Calculus of variations and Pontryagin's minimum principle. Minimum time problems. Minimum effort problems. Prerequisites: 16.509 and 16.513.

16.615 Solid State Drive Systems*
Elements of variable speed drive systems. Rectifier and chopper control of DC drives. Control of induction motors by AC voltage controllers. Frequency-controlled induction motor drives. Slip-power controlled wound-rotor induction motor drives. Synchronous motor speed control. Prerequisite: 16.515.

16.616 Computational Power System Analysis*
Power system matrices, power flow studies, fault studies, state estimation, optimal power dispatch, and stability studies. Prerequisites: 16.443 and 16.520.

16.617 Modeling and Simulation Techniques for Communication Networks
Overview of general architectures for broadband networks. Performance requirements, traffic management strategies, usage parameter control, connection admission control and congestion control. Stochastic processes models for voice, video and data traffic: Poisson processes, Markov chains and Markov-modulated processes; Queuing analysis: M/M/1, M/M/m, M/G/1 queues, fluid buffer models, effective bandwidth approaches; Simulation and computational modeling: discrete event simulation of transport and multiplexing protocols, statistical techniques for validation and sensitivity analysis. Prerequisite: 16.584 and Basic Programming Skills or Permission of Instructor.

16.618 Performance of Wireless Communications Networks
Introduction to fundamental concepts for resource management and performance evaluation of wireless communication networks. Performance of different access and modulation schemes in the presence of channel impairments. Techniques for modeling multipath and fading channels; Simulation and numerical approaches for generating fading signals and wireless link performance analysis; Methods for mitigating the influence of channel induced signal degradations using equalization, forward error control and feed-back control Prerequisites: Background in linear systems (16.509), stochastic processes (16.584 or equivalent) and some experience in programming or Permission of Instructor.

16.650 Advanced Computing Systems Hardware Architecture
Covers the latest advanced techniques in CPU design, floating point unit design, vector processors, branch prediction, shared memory versus networks, scalable shared memory systems, Asynchronous shared memory algorithms, systems performance issues, advanced prototype hardware structures, and future trends including TeraDash systems. Prerequisite: 16.561.

16.652 Parallel and Multiprocessor Architectures*
Study of principles of parallel processing and the design of hardware and software parallel computer architectures for a variety of models, including SIMD, MIMD. It also presents the issues related to designing and programming tightly-coupled shared-memory multiprocessor systems at the hardware level. Issues of memory structure, snoopy and directory-based caching, embedded memory consistency, cache controller coherency, processor interconnect strategies, and multiprocessor scalability, synchronization primitives, task scheduling, and memory allocation are covered. Prerequisites: 16.480 or 16.552 and 16.561.

16.653 Artificial Intelligence and Machine Learning*
Study of automated reasoning; representing change and the effects of actions; problem solving and planning. Includes the development of working programs that search, reason, and plan intelligently. Controlling physical mobile robot systems that operate in dynamic, unpredictable environments is covered. Building smart embedded chips for machine learning. Also covers neural networks, Fuzzy logic, genetic Algorithms and other approaches to machine learning. Prerequisites: 16.216 or Programming Skills and 16.322.

16.656 Fault Tolerant systems Design*
Covers the design and analysis of Fault-Tolerant Systems (hardware and software levels). Redundancy techniques are used for the creation of hardware redundancy, and information redundancy. Topics include: hardware and software architecture of fault-tolerant computers, fault tolerance through dynamic or stand-by redundancy, fault detection in multiprocessors, fault detection through duplication and comparison, fault detection using diagnostics and coding techniques, recovery strategies for multiprocessor systems, rollback recovery using hardware checkpoints and control digital logic for processor-cache-based checkpoints. Prerequisite: 16.561 or 16.650.

16.657 High-Speed Integrated Networks: Design and Evaluation*
Covers the design of high-speed multi-service networks, including gigabit networks. Hardware and software fundamentals for high-speed routers, bridges and gateways of emerging network technologies, including multimedia networks are covered. Topics include: High-speed real-time transport protocols, quality-of-service designs, latest hardware embedded systems for efficient routing algorithms, and compression. Wireless communication information networks and personal communications systems including mobile data networks are covered. Laboratories include the usage of high speed CISCO, ATM, and Myrinet switches and Network OOD and OOP and JAVA Network. Prerequisites: 16.216 or Programming Skills, 16.546, and 16.583.

16.658 Computer Network Security*
This three credit course covers the fundamentals of data network security. The concepts of data security will be examined through different algorithms. Different concepts on cryptographic systems (software and hardware) are classified. Different attacks on cryptographic systems are classified. Pseudo-random generators are introduced. The concepts of public and private key cryptography are developed. DES, IDEA, and AES are described as important representatives for private key schemes. The RSA and ElGamal public key schemes and systems based on elliptic curves are then developed. Signature algorithms, hash functions, key distribution, and identification schemes are treated as advanced topics. Some advanced mathematical algorithms for attacking cryptographic schemes are discussed. New methods for efficient hardware implementation of high-speed embedded systems are investigated, e.g. smart cards, cryptographic processors and co-processors, special-purpose hardware for cryptanalysis, DSP chips, etc. Prerequisite: Permission of Instructor.

16.659 Distributed Systems*
Covers principles of distributed systems, fundamentals of distributed computing models. The concepts of distributed file and directory services, distributed systems hardware and software design are studied. Topics include implementation of DS issues, reliability and availability, and fault tolerance. System bus structure for distributed systems, and design and implementation of the hardware distributed shared memory are studied. It also addresses logical synchronization and clock synchronization, resource allocation, self-stabilization of network protocols, graph partitions. Laboratories includes implementation of distributed systems (hardware and software) PVM, MPI and JINI. Prerequisites: 16.216 or Programming Skills and 16.583 or 16.713.

16.660 Mobile IP and Networking
Covers the fundamentals of mobile data communications. Introduces state-of-the-art mobile network architectures (Hardware and Software). Addresses an overview of wireless networks. Topics include architecture of existing mobile data networks: ARDIS, Mobitex, TETHRA, Merticom, CDPD and GPRS, wireless LAN technologies: 802.11, HIPERLAN, and wireless ATM. Studies the effects of mobility on different ISO layers, physical layer options, MAC layer in mobile environment, issues in mobile computing, mobile IP and DHCP. It also addresses mobility gateway technologies: MASE and eNetwork, inter-tech roaming and handover for wireless data networks. Laboratories include software tools for simulation of hardware Mobile networks. Prerequisite: 16.583.

16.661 Local Area Computer Networking
Characteristics and topology of Local Area Networks(LANs), WANs and MANs. Design of cable plants based on co-axial as well as fiber optic technologies. Data communication including transmission, reception, bandwidth, error correction and detection. LAN architecture with its layers. Applications TCP/IP, FTP, SMTP, TELNET, TFTP, HTML, HTTP and RTP. Addressing, sub-netting and CIDR. Design of ATM networks including addressing and end-to-end services with constant and variable bit rate**.** Communication links and their characteristics including digital links, frequency and propagation, distortion, dispersion and noise. Security and compression including threats against computers and users. Cryptography including secret and public key algorithms. Security systems with integrity and key management including Kerberos. PGP and Lempel-Ziv compression techniques. Prerequisite: 16.561 or 16.563 or Permission of Instructor.

16.663 Compiler Structures*

16.666 Storage Area Networks
A storage area network (SAN) is a separate network of storage devices physically removed from, but still connected to, the network. SANs evolved from the concept of taking storage devices, and therefore storage traffic, off the LAN and creating a separate back-end network designed specifically for data. In this course we will study the different SAN architectures and their relative advantages and disadvantages. Prerequisite: Permission of instructor.

16.669 Opto Electronic Devices
Topics of this class include: Semiconductor energy bands, PN junction principles, LED principles and device structures, Heterojunctions, Semiconductor Lasers, Quantum wells, Vertical cavity surface emitting lasers (VCSEL), PIN Photodiode, Avalanche Photodiode, Electro-absorption modulators. Pre-requisite: 16.360, 16.474 or 16.576 or 16.595.

16.684 Time Series Analysis and Forecasting With Applications*
Review of Estimation of Stochastic processes: Estimation of mean, variance, autocovariance, autocorrelation and normalized autocovariance of discrete stochastic processes; Generation of White Noise Sequences and tests for white noise; Difference operations. Linear Stationary models: Autoregressive (AR) processes, Yule-Walker equations, partial correlation. Moving Average (MA) processes, invertibility conditions and solution for MA parameters; Relation between AR and MA processes; Autoregressive Moving Average (ARMA) processes, formulation and solution for ARMA parameters. Levinson-Durbin and related algorithms: Deterministic and Probabilistic Methods; Forward-Backward Prediction; Lattice Methods. Gram-Schmidt Orthogonalization method; Burg Algorithm. Linear nonstationary Models: Autoregressive Integrated moving Average processes, differencing to induce stationarity and determination of the order of differencing. Model Identification and Diagnostic Checking: Examples for model identification; Portmanteau test and other tests for residuals to check for white noise. forecasting: Several methods for forecasting; Box-Jenkins forecasting functions, three types; Examples for the three types of forecasting; One-step linear predictors and confidence limits. Seasonal Time Series: Formulation of seasonal time series models and basic ideas of forecasting. Prerequisite: 16.584.

16.685 Statistical Communication Theory*

Chebyshev and Chernoff bounds. Statistics of random processes (RP) through linear systems. Concepts of entropy, information and channel capacity. Gaussian white noise. Concepts of signal space. Periodic RP. Aperiodic RP and Karhunen-Loeve expansion. Narrow-band Gaussian processes. Continuous-time matched filters. Discrete-time matched filters, discrete Wiener filter. Characterization of signal waveforms. Optimum demodulation of known and random signals in additive Gaussian white noise. Comparison of digital signaling methods. Optimization criteria: maximum aposteriori (MAP), maximum likelihood (ML). Discussion of maximum aposteriori and maximum likelihood receivers Elimination of intersymbol interference without and with Gaussian Noise. Optimization of equalizer coefficients: peak distortion criterion and mean square error criterion, Decision-Feedback equalization. LMS algorithm. Discussion of algorithms for adaptive equalization: recursive least squares, linear prediction and lattice filter. Prerequisites: 16.509 and 16.584 or Permission of Instructor.

16.687 Applied Stochastic Estimation

Review of random processes and key elements of probability theory. State space description of systems and random processes, relation to frequency domain techniques. Numerical methods of continuous and discrete time random system modeling. Optimal Kalman filtering for discrete and continuous random systems. Sensitivity analysis. Design considerations in the face of model uncertainty, numerical instabilities, bad data. Optimal smoothing. Non linear filtering. Parameter identification. Applications throughout. Prerequisite: 16.584.

16.688 Theoretical Acoustics*

Fundamental equations: elasticity and fluid equations. Linear Acoustics: equations of fluid at rest, transmission, reflection and propagation of planar waves, radiation of sound, scattering and diffraction of sound, acoustic waveguides and rooms. Acoustics in inhomogeneous media: sheared mean flow, varying sound speed. Nonlinear Acoustics: shock waves, nonlinear viscous effects. Prerequisite: Permission of Instructor.

16.690 Advanced Robotics Automation and Machine Intelligence*

Covers advanced foundations and principles of robotic manipulation; includes the study of advanced robot motion planning, task level programming and architectures for building perception and systems for intelligent robots. Autonomous robot navigation and obstacle avoidance are addressed. Topics include computational models of objects and motion, the mechanics of robotic manipulators, the structure of manipulator control systems, planning and programming of robot actions. Components of mobile robots, perception, mechanism, planning, and architecture; detailed case studies of existing systems. Prerequisite: 16.556.

16.692 Directed Studies

Provides opportunity for students to get a specialized or customized course in consultation with a faculty member. Prerequisite: Permission of Instructor and filing of a directed study agreement signed by the student and the instructor with the Electrical and Computer Engineering Department office.

16.710 Selected Topics I in Electrical and Computer Engineering

Advanced topics in various areas of Electrical and Computer Engineering and related fields. Prerequisite: Specified at time of offering.

16.711 Selected Topics II in Electrical and Computer Engineering
Advanced topics in various areas of Electrical and Computer Engineering and related fields. Prerequisite: Specified at time of offering.

16.725 Selected Topics III in Electrical and Computer Engineering
Advanced topics in various areas of Electrical and Computer Engineering and related fields. Prerequisite: Specified at time of offering.

16.729 Selected Topics IV in Electrical and Computer Engineering
Advanced topics in various areas of Electrical and Computer Engineering and related fields. Prerequisite: Specified at time of offering.

16.733 Advanced Graduate Project
The Advanced Project is a substantial investigation of a research topic under the supervision of a faculty member. A written report is required upon completion of the project. However, this course is graded only on a Pass or Fail basis and hence will not factor in the CGPA. It can be taken only once and the credits can be applied only to the requirements of the non-thesis option. The Advanced Project may evolve into a master's thesis and be converted to 16.743 by filing a petition before the final grade is submitted to the Registrar at the end of the semester. Prerequisite: Permission of Instructor and filing of a graduate project agreement signed by the student and the instructor with the Electrical and Computer Engineering Department office.

16.743 Master's Thesis in Electrical and Computer Engineering 3 credits

16.746 Master's Thesis in Electrical and Computer Engineering 6 credits

16.749 Master's Thesis in Electrical and Computer Engineering 9 credits

Requirement for 16.743, 16.746, and 16.749
A student cannot register for more than a total of three credits in his/her Masters degree program before completing two 3.0-credit Electrical and Computer Engineering graduate courses. Prerequisite: Permission of Instructor thesis advisor and filing of a thesis agreement signed by the student and the instructor thesis advisor with the Electrical and Computer Engineering Department office.

16.751 Doctoral Dissertation in Electrical and Computer Engineering 1 credit

16.753 Doctoral Dissertation in Electrical and Computer Engineering 3 credits

16.754 Doctoral Dissertation in Electrical and Computer Engineering 4 credits

16.755 Doctoral Dissertation in Electrical and Computer Engineering 5 credits

16.756 Doctoral Dissertation in Electrical and Computer Engineering 6 credits

16.757 Doctoral Dissertation in Electrical and Computer Engineering 7 credits

16.759 Doctoral Dissertation in Electrical and Computer Engineering 9 credits

Requirement for 16.751, 16.753, 16.754, 16.755, 16.756, 16.757, and 16.759
Written approval by the dissertation advisor; matriculated status in the doctoral program in EE. No more than 9 credits of doctoral dissertation research may be taken before passing the doctoral qualifying examination. No more than 15 credits of doctoral dissertation research may be taken before passing the defense of the thesis proposal examination. Prerequisite: Permission of Instructor dissertation advisor and filing of a dissertation agreement signed by the student and the instructor dissertation advisor with the Electrical and Computer Engineering Department office.

16.763 Continued Graduate Research 3 credits

16.766 Continued Graduate Research 6 credits

16.769 Continued Graduate Research 9 credits

Requirement for 16.763, 16.766, and 16.769
Students who do not meet the requirement of 16.743, 16.746, 16.749, 16.751, 16.753, 16.754, 16.755, 16.756, 16.757, and 16.759 for theses or dissertations may register for 16.763, 16.766, and 16.769. The credits cannot count toward their degree programs. Prerequisite: Permission of thesis/dissertation advisor.

Department Faculty Profiles

Alkim Akyurtlu

B.S.	Virginia Polytechnic Institute
M.S.	Pennsylvania State University
Ph.D.	Pennsylvania State University

Research Interests: Theoretical and computational electromagnetics with applications to electro-magnetic wave interactions with complex materials, antenna theory and design, and micro-waves. Modeling of electromagnetic scattering and propagation.

Craig Armiento

B.S.	Electrical Engineering, Manhattan College
S. M.	Electrical Engineering, Mass. Institute of Technology
E.E.	Electrical Engineering, Mass. Institute of Technology
Ph.D.	Electrical Engineering, Mass. Institute of Technology

Research Interests: Fiber optic communication systems; photonic device design, Dense Wave-length Division Multiplexing (DWMD) technologies, optical network design, semiconductor device physics, process development for III-V semiconductors, optical subsystem development using hybrid integration, access network architectures.

Kavitha Chandra

B.E.	Bangladore University
M.S.	University of Massachusetts Lowell
D. Eng	University of Massachusetts Lowell

Research Interests: Performance analysis of wired and wireless communications networks; network traffic characterization and traffic control, physical layer modeling of wireless channels, computational models for acoustic and electromagnetic wave scattering.

George P. Cheney

B.S.	Lowell Technological Institute
M.S.	Lowell Technological Institute

Research Interests: Digital and analog design, embedded real-time systems.

Tingshu Hu

B. S.	Shanghai Jiao University, China
M.S.	Shanghai Jiao University, China
Ph.D.	University of Virginia

Research Interests: Nonlinear systems theory, control systems with saturation, optimal control and optimization techniques, robust control, control applications to mechanical systems and biomedical systems.

Oliver Ibe

B. Sc.	University of Nigeria
S.M.	Mass. Institute of Technology
M.B.A.	Northeastern University
Sc. D	Mass. Institute of Technology

Research Interests: Mobile and fixed wireless communications, voice over IP networks, communications systems performance analysis, stochastic systems modeling, and statistical systems processing.

Xuejun Lu

B. S.	Peking University
M.S.	University of Texas at Austin
Ph.D.	University of Texas at Austin

Research Interests: Silicon based nanophotonics, uncooled QDIP sensors, Nonlinear thresholding optical gates, guided wave optical Interconnects, Ultra high-speed transceiver interface, Optical CDMA transceivers.

Yan Luo

B.E.	Huazhong University of Science & Technology, China
M.E.	Huazhong University of Science & Technology, China
Ph.D.	University of California Riverside

Research Interests: Network Processors, Low Power Processors, Internet Router and Web Server Architectures, Parallel and Distributed Processing, Embedded Systems, Simulation and Performance Evaluation.

Mufeed Mah'd

B. S.	Kuwait University
M.S.	University of Jordan
Ph.D.	University of Western Ontario, Canada

Research Interests: Digital signal and medical image processing; nuclear medicine: Positron Emission Tomography (PET), Single Positron Emission Tomography (SPECT); Computerized Tomography (CT); Magnetic Resonance Imaging (MRI). Image reconstruction and restoration; image registration and fusion; real time signal/image code development and hardware implantation. Reliability analysis: fault tolerant control systems; system modeling; estimation and identification; computational methods and numerical analysis.

Martin Margala

Dipl. Ing.	Slovak Technical University, Slovakia
Ph.D.	University of Alberta, Canada

Research Interests: Low-Power Memories, Adaptable Circuits and Architectures, SIMD and MIMD Processing, Analog-to-Converter Design, Design for Reliability, multi-Gigahertz Testing, Embedded Testing, Design for Testing Room Temperature Terahertz Circuits and Systems, Ballistic Operation.

Dalila B. Megherbi

Dipl.	Ecole Nationale Polytechnique (ECE)
M.S. , ECE	Brown University
M.S., Appl. Math	Brown University
Ph.D.	Brown University

Research Interests: Distributed Systems and High Performance Computing; High Speed Networks/ Networking; Parallel Computers/Computing; Artificial and Machine Intelligence; Computer Vision and Image Processing including Applications to Home-land Security and Bio-Engineering; Optical and Digital Signal Processing; Remote Sensing and large Image Data Compression; Knowledge and Data Engineering and Applications; Design Methodologies and Tools for Architecture Design, and Fault Tolerance Systems; Embedded Real-Time Systems and Architectures; MEMS and Computational Modeling for Nanotechnology Applications including DNA Computational Processing and Analysis.

Sam Mil'shtein

B. S.	State University of Odessa
M.S.	State University of Odessa
Ph.D.	University of Jerusalem, Israel

Research Interests: Development of novel quantum well and high speed transistors. Design of noise immune amplifiers, low distortion switches, linear mixers. Systems for information coding and scrambling. Electronics for bio-engineering and bio-metrics. Infra Red imaging for medical applications.

Kanti Prasad

B. Sc.	Agra University
B.E.	University of Roorkee
Ph.D.	University of South Carolina, PE

Research Interests: Reliability analysis and enhancement for GaAs and silicon devices through novel techniques; Design of protocol controllers for communication systems including wireless; ASIC chip design for communication, controls, microprocessor and memory including graphical interfaces; Network Security, Development of Sensors deployable in Transportation Systems; Integration of ITS technology with Imagery and Geospatial databases for building systems for the national security.

Tenneti C. Rao

B. Sc.	Andhra University
B.E.	Indian Institute of Science, Bangalore
M.E.	Indian Institute of Science, Bangalore
Ph.D.	Indian Institute of Science, Bangalore

Research Interests: Novel transmission line and waveguide structures for millimeter wave propagation; Development of new analytical tools to analyze monostatic and bistatic scattering cross sections from a terrain covered with snow or vegetation; Chiral materials and their possible uses for mm wave applications; Determination of the material parameters by near field measurements; Cavity backed aperture antennas. (Work is analytical, numerical and experimental.)

Ziyad M. Salameh

Dipl.	EE, Moscow Power Engineering Institute(w/ Honors)
M.Sc.	University of Michigan
Ph.D.	University of Michigan

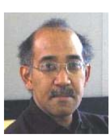
Research Interests: (1) Renewable Energy Lab (REL): Hybrid Wind/Photovoltaic (PV) for stand alone and utility interactive systems (2) Battery Evaluation Lab (BEL): Mathematical modeling, performance evaluation (capacity, efficiency, state of charge, impedance, charge/discharge rates) (3) Power Electronics Lab (PEL): Static Var Compensator SVC, operation, design using new technologies (MCTs), (4) Electric Vehicle Evaluation Lab (EVL): Electric Vehicle: electric vehicle battery charger performance evaluation. Electric vehicle battery evaluation, capacity and efficiency. Electric vehicle range as a function of the battery capacity and battery type.

Joel Therrien

B.S. Physics, U. Mass-Lowell
M.S. Energy Engineering, U. Mass-Lowell
Ph.D. Physics, U. Illinois Urbana-Champaign

Research Interests: Nanoscale sensors, nanoelectromechanical devices, chemical/biological sensors, optoelectronics. Scanning Probe Microscopy for nanomanufacturing. Nanomanufacturing methods for electronic devices.

Charles Thompson



B. S.	New York University
M. S.	Polytechnic Institute of New York
Ph. D.	Massachusetts Institute of Technology

Research Interests: Physical acoustics, computational modeling, nonlinear systems, telecommunications.

Anh Tran

B. Sc. National Taiwan University
M. S. University of Rhode Island
Ph. D. University of Rhode Island

Research Interests: Current research interest is in the studies of exclusive-OR switching circuits (also known as Reed-Muller polynomial or expansion), which include minimization, analysis of transient behavior, hazard-free design, and applications to universal logic modules and programmable devices.

Xingwei Wang

B.S. Zhongshan (Sun Yat-sen) University, Guangzhou, China
M.S. Virginia Tech
Ph.D. Virginia Tech

Research Interests: Optical biosensing and biomedical devices; nanoprobe design and fabrication; self-assembled nanostructures; electromagnetic wave propagation; temperature, pressure, acoustic, strain, and chemical sensors.

Jay A. Weitzen

B. S. University of Wisconsin, Madison
M. S. University of Wisconsin, Madison
Ph. D. University of Wisconsin, Madison

Research Interests: Wireless communication systems, digital communication systems, navigation and position location systems.

Cost & Financial Aid

Undergraduate

UMass Lowell is value; for 2011-2012, tuition and fees, room & board for in-state full-time undergraduate students is only $20,817 for 1 academic year. Tuition and fees alone cost; $11,297 for in-state students, $17,350 for out-of-state students.

Graduate

The total cost of attending Graduate School depends on the residency status of the student - whether Massachusetts resident (at time of application), New England Regional resident (if there is no comparable program in the student's own New England state) , or out-of-state (including foreign students). The cost is dependent upon number of credit-hours registered in a given semester, up to "full time" status of 12 credit-hours. The cost consists of two major items, tuition and fees, which can be obtained from the Graduate School website.

A limited number of Teaching and Research Assistantships are available for qualified full time graduate students. These positions are assigned by the student's department and are subject to the agreement between UMass Lowell and UAW/Graduate Employees Organization. Therefore, all requests for teaching assistantships should be directed to the Departmental graduate coordinator or chairperson. Historically, many full time graduate students in the Department of Chemical Engineering have received either a full or half-time Assistantship at some point in their graduate program. Note, however, that this is not a guarantee of support for all full time students.

A student who signs a teaching assistantship contract after April 15th is legally bound to honor this agreement and may not accept an offer from another institution, in accordance with the 1988 Council of Graduate Schools resolution governing this matter. Students interested in receiving an assistantship should file their applications for admission to a degree program as early as possible, checking the appropriate box on the application form. A student who is to receive an assistantship will be notified and sent a contract directly by the department. Reappointments in succeeding years are contingent upon satisfactory performance of duties as well as academic achievement. Master's degree candidates may hold an assistantship for a maximum of two years and doctoral candidates for a maximum of four years.

To ensure that teaching assistantships are awarded to the most qualified individuals, the Graduate School has established the following requirements:

1. No teaching/research assistantship may be awarded to a graduate student with incompletes, F's, or U's on his or her transcript.
2. No teaching/research assistantship may be awarded to a graduate student with a cumulative grade point average under 3.0 on the official transcript.
3. No university-funded teaching/research assistantship may awarded to a master's degree candidate if he/she has completed the total number of credits required for his/her program.
4. Level 3 teaching/research assistantships may only be awarded to graduate students who have reached doctoral candidacy (i.e. completed all course work, oral/written and language examinations) and are enrolled in dissertation research.

Research assistantships are available through special arrangements with individual research advisors. Individuals interested in research assistantships should contact departmental faculty members concerning the availability of this form of financial aid. Students who receive teaching or research assistantships must be matriculated and full-time (minimum of 9 credits/semester).

The amount of the Teaching or Research Assistantship for each semester or academic year is set according to agreement between UMass Lowell and the UAW/Graduate Employees Organization. For in-state students, a full *or* half-time Assistantship carries a taxable stipend plus a full tuition and fees waiver for each semester. For out-of-state students, a full *or* half-time Assistantship carries the same taxable stipend as the in-state students, plus a full out-of-state tuition waiver. However, the out-of-state student is still responsible for any fees.

Teaching & Research Assistantship Stipend/Waiver Information:

(for full year, double the amounts shown)

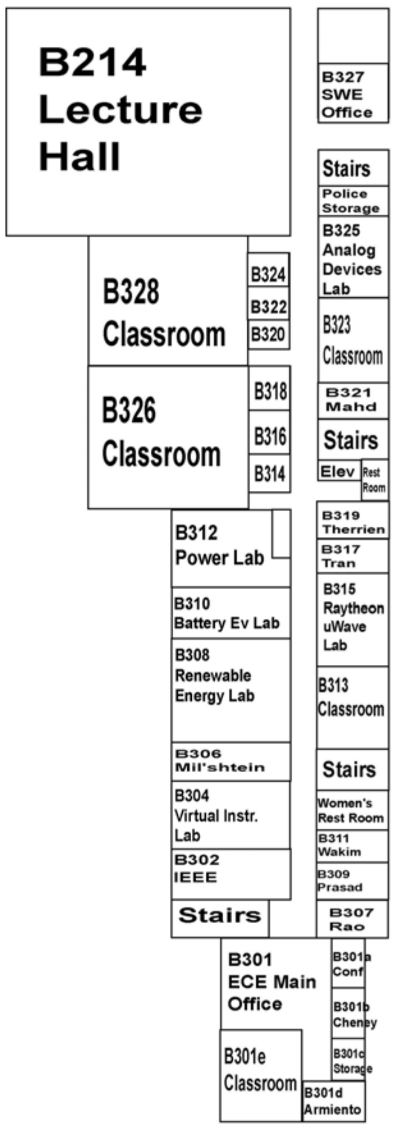
Item	half-time	TA/RA per semester	full-time	TA/RA per semester
	in-state	out-of-state & foreign	in-state	out-of-state & foreign
stipend	$3349	$3349	$6,504	$6,504
total TA/RA value per semester	$7611	$8480	$12,265	$16,199

Education Costs - Full time (9 credits) per year:

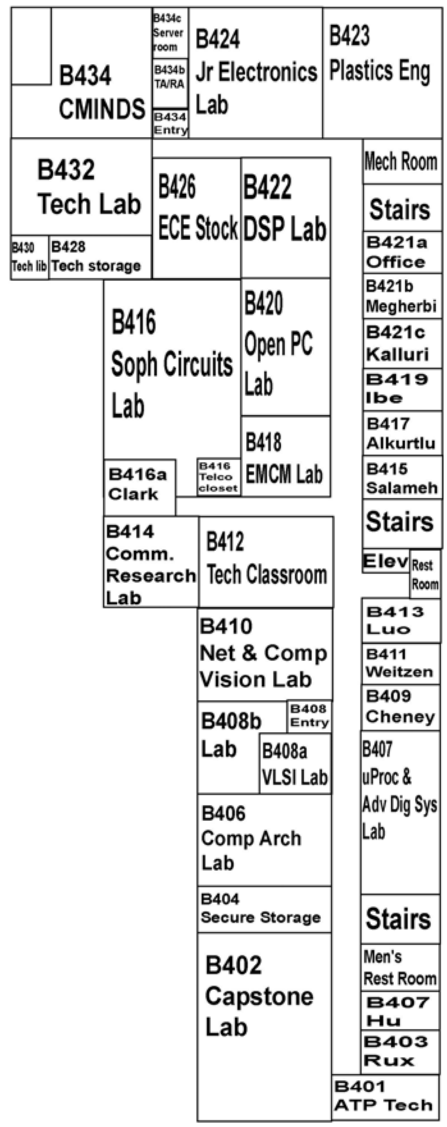
In-state: $10,704 Out of state: $19,804

New England Regional & New England Proximity: $7380

Maps of ECE Facilities: Ball Building



Ball Hall 3rd Floor



Ball Hall 4th Floor

REVISED ADMISSIONS STANDARDS for College of Engineering as of 11/25/2008

The University Admissions Office uses a common minimum admissions standard established by the Commonwealth of Massachusetts Board of Higher Education for the University of Massachusetts. There are different standards for Freshmen applicants, Transfers, Non-traditional and Special Admissions. The College of Engineering sets additional criteria over and above these minimum standards. In addition, the Admissions Office considers high school class rank, SAT-I totals and high school GPA, and assigns a numeric value to each student based on an aggregate of the above three criteria.
The following are the minimum admissions standards for First Year students to the College of Engineering:

- Minimum weighted HS GPA of a 2.75 on a nominal 4.0 scale
- Minimum combined SAT I Math + Critical Reading total score of 1000 (max 1600)
- Minimum weighted average of grades from all HS math and physical science courses (Physics, Chemistry) of 2.50 on a 4 point scale
- Math proficiency as evidenced by one or more of the following:
  - Sufficient HS math courses to allow entry into 92.131 Calculus I during first semester (students should have taken & passed Algebra I, Algebra II, Geometry and either Trigonometry, Precalculus or Calculus) OR
  - Minimum score of 3 or more (out of 5) on the Advanced Placement Calculus AB or BC exam OR
  - College-level Calculus I with grade of C or better
- At least 3 natural science courses (Chemistry, Physics, Biology, Earth Sciences, Anatomy & Physiology), two of which must have a lab component, AT LEAST ONE of which is either HS Physics or Chemistry. It is STRONGLY recommended that applicants in Engineering have BOTH Physics and Chemistry.
- At least 16 academic courses, all of which must be at the College Prep level or higher

Exceptions: When applicants show a SAT M+V score less than 1000 or HS GPA below 2.75, they will be considered for admissions according to the following slidiing scale:

- if HS GPA between 2.50 and 2.75, SAT M+V must ≥ 1100
- if HS GPA <2.50, SAT M+V must ≥ 1200
- if SAT <1000, GPA must ≥ 3.0

Students who do not meet these minimum standards for the College of Engineering and are admitted initially to the University in Colleges other than Engineering) will only be allowed admission to the College of Engineering AFTER they have successfully passed 92.131 Calculus I or equivalent with a minimum "C" grade AND only after they have successfully completed at least one full semester at UMass Lowell as a full time student with a GPA of at least 2.0. Students who meet these criteria may file a petition to change majors which requires the consent of the Department Chair and Dean of the College into which the student is transferring.

Some students may be a eligible for the Patricia Goler Fellows Program, which provides a structured plan for a limited number of freshmen who are first in their families to attend college and/or whose family earnings are less than 150% of the statewide poverty level. Eligible students must have earned a GPA of 2.5, and a minimum combined SAT of 850. Students in this Program who wish to enroll in Engineering must meet the minimum criteria for admissions or transfer into Engineering.
Students admitted into the College of Engineering may declare a Departmental affiliation at the time of admission, although there is no requirement for them to do so until the end of their Freshman year.
Transfer students are admitted using a different set of Admission standards:

- Students with 12-23 transferable college credits and a minimum 2.5 college GPA
- Students with 23 transferable college credits, a minimum 2.0 college GPA, and a high school transcript which meets the admissions standards for freshmen applicants

Students with 24 transferable credits and a minimum 2.0 college GPA.

The Office of Admissions determines whether or not courses taken elsewhere are eligible for transfer and conducts a preliminary evaluation. The University of Massachusetts Lowell subscribes to the Commonwealth Transfer Compact and Joint Admissions Programs. In addition, the applicants' records are individually evaluated by each department's transfer coordinator to determine whether or not they fulfill departmental program requirements.
For more information go to UMass Lowell Office of Undergraduate Admissions.

Office of Undergraduate Admissions

University of Massachusetts Lowell
Dugan Hall Rm 110
883 Broadway St.
Lowell MA 01854-5104
(800) 410-4607 or (978) 934-3931 Fax (978) 934-3086
email: admissions@uml.edu
web page: www.uml.edu/Admissions

Office of Student Financial Assistance

University of Massachusetts Lowell
McGauvran Student Center, Suite 7
71 Wilder Street
Lowell, MA 01854-3089
(978) 934-4220   Fax (978) 934-3009
email: see web site for list of counselors
web page: www.uml.edu/admin/finaid

Office of Residence Life

University of Massachusetts Lowell
Cumnock Hall
One University Avenue
Lowell, MA 01854
(978) 934-2100 Fax: (978) 934-3042
web page: www.uml.edu/student-services/reslife

The Graduate School

University of Massachusetts Lowell
Dugan Hall
883 Broadway St., Lowell MA 01854
(800) 656-GRAD or (978) 934-2381 C Fax 978 934-3010
email: Graduate_School@uml.edu
web page: www.uml.edu/grad

College of Engineering

University of Massachusetts Lowell
Kitson Bldg. 311
One University Avenue, Lowell MA 01854
(978) 934-2570   Fax (978) 934-3007
email: engineering@uml.edu
web page: engineering.uml.edu

Dept. of Electrical & Computer Engineering

University of Massachusetts Lowell
Ball Hall 301
One University Avenue, Lowell MA 01854
(978) 934-3300   FAX (978) 934-3027
web page: electrical.uml.edu

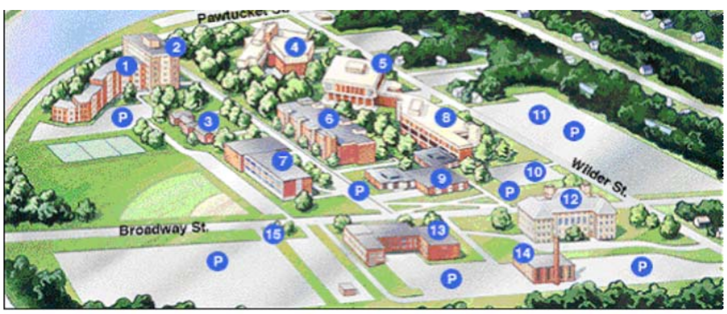
Campus Maps

North Campus

	Building Name
1	Olsen Hall (OS)
2	Ball Hall (BL)
3	Engineering Building (EB)
4	Olney Hall (OH)
5	Pinanski Energy Center (EC)
6	Riverside Lot
7	Costello Gym
8	Falmouth Hall (FA)
9	Power Plant/Garage
10	Pasteur Hall (PA)
11	Kitson Hall (KI)
12	Southwick Hall (SO)
13	Smith Hall
14	Alumni Library
15	Cumnock Hall

	Building Name
16	Bus Stop
17	Lydon Library (LL)
18	Eames Hall
20	Leitch Hall
21	Fox Hall
22	Donahue Hall
23	Riverwalk
24	Bourgeois Hall
25	Recreation Center
26	Edward A. LeLacheur Park
27	Institute for Plastics Innovation
28	Wannalancit
29	Tsongas Arena

South Campus



	Building Name
1	Sheehy Hall
2	Concordia Hall
3	Allen House
4	Durgin Hall (DR)
5	O'Leary Library (OL)
6	Weed Hall (WE)
7	Dugan Hall (DU)

	Building Name
8	McGauvran Student Union (SU)
9	Southside Cafe/Dining Hall
10	Bus Stop
11	Lovejoy Lot
12	Coburn Hall (CO)
13	Mahoney Hall (MA)
14	Power Plant (South)
15	Riverview Lot

Electrical & Computer Engineering
University of Massachusetts Lowell
One University Avenue
Lowell, Massachusetts 01854
web: electrical.uml.edu

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