Student Ownership of Education Plans: The New Electrical Engineering Curriculum at The Cooper Union

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Introduction.

Recently, The Cooper Union initiated sweeping changes in the undergraduate electrical engineering curriculum. As of the 2004-05 academic year, the first generation of students to go through this curriculum are sophomores.

Students are given both the opportunity and the responsibility of becoming owners of their education plans. Strong faculty guidance is provided to ensure integrity, and is essential for crafting well balanced plans of study. Flexibility in the curriculum, which allows students to pursue various areas of interest and undertake multidisciplinary projects, must be balanced against a rigorous foundation. Emphasis on project work, applications and professional practice must be balanced against developing strong theoretical and analytical skills.

This paper describes the new curriculum, the principles underlying it and the plan for its deployment. Although in many respects the Cooper Union is a unique institution, it is hoped that our approach can provide a roadmap for curricular innovations in other engineering schools.

An Overview of Electrical Engineering at The Cooper Union.

The Cooper Union for the Advancement of Science and Art is a small school located in lower Manhattan, with total enrollment in the range 1000 to 1200 students. The college has schools of art, architecture and engineering. Founded by the industrialist Peter Cooper in the 19th century, The Cooper Union offers a full-tuition scholarship to every student based upon academic merit, and a fundamental precept is that students are admitted solely on merit. The engineering school offers (ABET accredited) Bachelor and Master of Engineering degrees in chemical, civil, electrical and mechanical engineering, as well as a Bachelor's degree in general engineering. The B.E. degree requires 135 credits of study over four years, on a semester basis. The M.E. degree requires 30 additional credits, of which 6 are a thesis or project. The graduate program is actually called an Integrated Master's Program, in that students generally can start taking graduate level courses while still undergraduates, and can complete the requirements for the Master's degree in a fifth year, or less.

As part of the preparation for ABET accreditation in 2000, the Department adopted the following mission statement for the electrical engineering program:

> To develop a "compleat" engineer- highly trained and able to practice in a professional manner, to lead a design team of a company and grow as technology advances, to express himself/herself in written and oral form, to be able to function as a project engineering immediately upon graduation, or undertake graduate studies in a variety of professional fields.

The three primary objectives of the program are:

1. To produce an engineer capable of functioning as a project engineer upon graduation.
2. To develop professional design skills.
3. To produce and engineer capable of professional-level written and oral expression.

We recognize that many of our students will not become or remain designers. While their training will allow for this option, and certainly many take this route, many others will pursue a different career option. This country needs both technical leadership and a strong research base. Many of our students will fulfill this role in the future as they have in the past. The curriculum must allow the student to develop his/her intellectual as well as design skills. Engineering graduates, by virtue of their training and ability, must be prepared for "anything." They are viewed as extraordinary problem solvers, and hence many other industries, including banks and brokerage houses, hire engineers not only for their technical skills but also for employment in their primary business. Engineering education can also serve as an excellent basis for careers in medicine and law.

The environment we create for our students is critical. In order to achieve these objectives, for example, the curriculum has long had no engineering laboratory courses- only project courses in which students work in teams on open-ended design problems, not rote experiments. These projects course start in the freshman year and culminate in a year-long senior design project. Faculty work closely with the students, and encourage independent thinking and challenge students to push themselves, to reach their full potential. The result is the professional development of young project engineers who can both design and direct small groups of dedicated professionals. The theory covered in courses is also rigorous, and students are prepared for and introduced to graduate level work while still in undergraduate school.

The small size of the school, strong abilities and high expectations of our students has led to this general attitude. While we have long felt our curriculum was strong, we have now put in place a structure, we believe, which better fits our objectives. It is not a mere reshuffling of courses. The key to our approach, and perhaps the greatest challenge to its success, is that we hope to develop the maturity of our students by demanding it of them. The students have a deeply vested interest in their educational plans, and we are thus making them active participants, rather than passive ones. This student self-awareness necessitates strong faculty guidance, openness and communication, including a clear and open presentation of the engineering curriculum, its objectives and the principles underlying it.

Multiple Tracks in the New Electrical Engineering Curriculum.

Several key concepts underlying the new curriculum are:

- Organizing the curriculum into multiple tracks to permit flexibility for students within a discipline, and concentrations for students outside the discipline.
- Close coordination between the faculty in electrical engineering and faculty from other Departments, such as mathematics and physics.
- Extensive use of project and research based learning experiences to complement rigorous theoretical studies.
- Significant exposure to the principles of professional practice, including written and oral communication and working in multidisciplinary teams.

Starting from a minimal set of electrical engineering gateway courses, and built on a foundation of core science and liberal arts courses, the curriculum extends into three tracks:

- signal processing and communications engineering;
- electronics systems and materials engineering;
- computer engineering.

The differences among the tracks are carefully limited so that students can target areas of interest without sacrificing breadth. Every track is comprised of a number of concentration courses, which provide depth in the particular subject. But there is also significant overlap among the tracks to ensure breadth. Prerequisite chains are streamlined to create minor concentrations for students from other engineering disciplines, and also to facilitate students taking courses out of the standard sequence (in certain cases). The curricula for these tracks are shown in Tables 1, 2 and 3, respectively.

Students can complete all required courses, except for senior capstone design projects, by the end of third year. The degree requirements include a sufficient number of technical elective credits to permit students to minor in another discipline, or to specialize further. There is also flexibility in the nature of the non-technical electives which students take.

The junior year generally has been the year when electrical engineering students have been required to take at least one course from each of the major areas within the field, such as digital signal processing, communications, VLSI, engineering electromagnetics and computer architecture. Some required courses had remained in the fourth year. The new curriculum has taking this concept to the ultimate point of leaving an entirely elective fourth year (aside from senior design projects). A desirable result is that students can conduct more meaningful projects in a wider range of fields if they already have some background prior to their senior year. A student interested in wireless communications, for example, will have taken communications in the third year, and perhaps will take a graduate course in communications concurrently with the senior project. This also enables students to get better and more interesting summer jobs or internships between their junior and senior years More fundamentally, by exposing students to these various subjects, they identify areas that interest them earlier, and they become more motivated in their studies.

Expanding upon this point, one of the principles underlying the curriculum is to expose students to engineering early on. Computer architecture (ECE151), for example, has been changed from a third year to a second year required course. Historically, digital logic design (ECE150) started as an elective, then became a required third year course, then second year, and eventually a first year course. Once freshman EE students were mandated to take the course, it became the gateway course into electrical engineering. Students work in teams on design projects in the course, and are introduced to laboratory practices and basic instrumentation. The course also presents theory, which is given weight equal to the project work, and introduces certain analog concepts, for example in the context of interfacing circuitry. By the nature of the subject, it does require prior knowledge of calculus through differential equations or extensive electrical circuit theory and so is the most natural introduction to electrical engineering. This not only exposes students to electrical engineering early, but also indicates to certain students that perhaps they do not want to pursue studies in the field, and they transfer to other Departments.

In the new curriculum, this gateway concept is extended to three central courses, one from each of the tracks:

- ECE150 Digital Logic Design for computer engineering;
- ECE141 Circuits & Electronics I for electronic systems and materials;
- ECE111 Signal Processing & Systems Analysis for signal processing & communications.

The multi-track approach permits a separation of courses, so that students outside the EE discipline can study such topics as spectral analysis and multimedia signals without an extensive background in circuits and electronics. It is expected that students in other major disciplines, or general engineering students, may avail themselves of the opportunity to obtain some background in this area, such as by taking a minor concentration of four or five courses.

In order for this to be successful, the syllabi of a number of interrelated courses must be examined, with topic sequencing and selection rethought. The challenge, from the perspective of an electrical engineering curriculum, is to retain strong linkages among these three tracks, so that students see a comprehensive whole, not unrelated topics.

As an example, an introductory course in signal processing and systems analysis, targeted to second year or even first year students, would necessarily avoid a presumed background in circuits and electronics. Instead, concepts such as spectral analysis and both analog and digital signals and systems can be presented on their own, without significant prerequisite knowledge. This course is manifested in the new curriculum as ECE111. The foundation for the syllabus is the recent textbook *Signal Processing First*[1], but some topics from the text will be left for more advanced courses and other topics will be brought in. For example, random signals and signal-space (visualizing signals as vectors, critical to estimation, detection and decision algorithms) will be discussed in the course. In addition, connections to analog circuit analysis will be presented, and this course together with the sophomore level circuits and electronics courses will present a cohesive whole. ECE111 is supported by a zero credit seminar which presents the scientific computation package MATLAB[2]. The MATLAB seminar will emphasize good programming style and visualization as well as complement the discussion of signals and systems in ECE111.

To some extent, of course, linking topics covered in different courses has always been a concern. In the past, the sophomore level courses on circuit analysis also provided an introduction to signals and systems, in the analog context, but were separate from the sophomore level electronics course. Now, the circuits and electronics topics are covered in common courses, but the signal and system concepts are separated out. This allows circuit analysis methods and circuit models to be tied more closely to the context in which they are used, and also permits a preliminary discussion of digital signal processing in the gateway course on signals and systems. As a side benefit, the required third year course on digital signal processing (ECE114) can cover more advanced topics.

Core Courses and Liberal Arts Studies.

All engineering students at The Cooper Union take the same core courses in physics, chemistry, mathematics, humanities and social sciences in their first two years. They also attend professional development seminars, where topics such as ethics, communication and entrepreneurship are discussed.

Close coordination with the math and science faculty plays a vital role. With the technological explosion characteristic of the Information Age, electrical engineering is becoming increasingly dependent on advanced mathematical and scientific concepts. Math and science faculty play a vital role in the education of undergraduate electrical engineering students. The role can extend beyond course work by exploiting opportunities to collaborate with electrical engineering faculty on practical projects and applied research.

Electrical engineering faculty team teaching with faculty from math or physics has been used for over ten years in various situations at The Cooper Union. However, this close coordination can extend beyond team teaching in selected courses. The faculty from the various Departments meet regularly and discuss broad curricular issues as well as particular topics covered in specific courses. Mathematics and physics courses are coordinated very closely with electrical engineering courses, while ensuring the math and physics courses accommodate the needs of other engineering majors at the same time.

This coordination impacts the sequencing of undergraduate math courses taken by electrical engineers. For example, electrical engineering students take differential equations a semester earlier (Fall of second year, as opposed to Spring of second year) compared to other engineering students. It also impacts the selection of examples and applications in courses, coverage of particular topics, and elective offerings. For example, the upper level math elective in linear algebra (MA326) covers infinite dimensional spaces (Hilbert space) as a tie-in to signal processing. As another example, there will be a greater emphasis on quantum mechanics in the electrical engineering section of modern physics (PH214), which is taken at the same time as a second electronics course which emphasizes semiconductor materials (ECE131). The electrical engineering section of differential equations (MA240) devotes more time to Laplace transforms and Fourier series. EE students will be exposed to random signals in the gateway signal processing course (ECE111) which is taken in the same semester as probability (MA224). The net result is that the team teaching concept is applied even when the faculty are not in the same classroom.

Historically, in the third and fourth years, students have been required to take 12 credits (3 credits per semester) in humanities and social sciences. However, in the new curriculum, of these 12 credits, up to 6 can be taken in non-technical areas other than humanities and social sciences. For example, we would expect many students to avail themselves of the opportunity to take courses in art and architecture. This would hopefully foster greater interaction among the three schools at The Cooper Union, a goal that has been long sought after but difficult to achieve. Other students may take, for example, business courses, and others will opt for electives in humanities and social sciences. In the past, engineering students with an interest in art and architecture courses we permitted to take them, but these courses did not count towards the degree requirements.

Projects Courses.

The digital logic design (ECE150) and computer architecture (ECE151) are required EE courses in the first and second year, respectively, which are project oriented. Although they cover theory as well, open-ended design problems requiring actual hardware implementation and testing in the laboratory are an integral part of the courses. In conjunction with the first year general engineering design course (EID101), students have significant experience with project management issues, working in project teams, and preparing various types of technical written and oral presentations by the time they enter the junior year.

In the junior year, the projects courses ECE193/ECE194 are taken in the fall and spring semesters, respectively. The projects through the year have increasingly large scope, and prepare students for their senior design projects, as well as providing a practical component to their courses in electronics and other subjects.

Courses ECE195/196 constitute the year-long senior design project. Students work in small groups on projects chosen with the advice and consent of the faculty advisor. Projects may be in any area of electrical or computer engineering, or multidisciplinary areas such as biomedical engineering. Students perform all aspects of project management, such as scheduling, budgeting, system design, and developing milestones, as well as technical work including hardware and software implementation, testing and performance evaluation.

In the junior and senior projects courses, students give several spontaneous and rehearsed oral presentations, prepare written reports, and attend weekly lectures covering topics such as ethics, safety, design methodology, technical writing and communication. It is important to note that students are not segregated in these projects courses by their chosen track. This fosters multidisciplinary work, and in fact the individual members of the project team are not permitted to focus too narrowly on highly specialized issues within the project. Every student is expected to have the broader view of the project as a whole.

The senior project is actually called a thesis. A thesis is a statement. In other words, the students are expected to identify and address a particular need, and develop an appropriate solution. The initial goal is to achieve a functioning system, which must be accomplished at least one month before the end of the academic year. Afterwards, students undertake the completion of the prototyping cycle, which may involve improving the circuit implementation or obtaining precise performance evaluations. Advanced students are strongly encouraged to complete their project early and commence a Master's thesis.

Students have the flexibility to select projects that interest them, based on their own ideas, or projects proposed by faculty. Faculty provide guidance to assist students to develop project ideas with appropriate scope. Multidisciplinary projects performed in collaboration with outside entities, such as telecommunication companies and hospitals, or other departments in the school are encouraged.

Student Ownership of the Curriculum.

So far, various issues and concepts related to the curriculum have been discussed. At this point, the process for enabling student ownership of education plans can be presented. The basic mechanism is to provide flexibility in a structured context. This presents a challenge not only with respect to individual students, each of which must pass through a complete and appropriate education, but also in terms of realizing flexibility and variety in a small Department.

The first mechanism for flexibility is the multi-track approach. There is not tremendous variation among the tracks, intentionally. All students take communication networks (ECE103), for example. There was in fact a discussion as to whether it should be a required course for students in the electronic systems and materials track. It was decided that so many applications are tied to the subject that it would be left as a required course. However, a student in that track may decide to postpone taking the course until the senior year, in order to make room for another elective in the junior year. As another example, many EE students, even those not particularly interested in computer engineering, take programming languages (ECE161). A student seriously interested in computer engineering would want to take it no later than the sophomore year, so that more advanced courses such as data structures (ECE165) and software engineering (ECE361) could be taken in the junior year, so that, in turn, significant projects in computer engineering and advanced electives could be taken in the senior year.

It is important to note that computer engineering as a separate program does not exist at The Cooper Union. Students that go on to graduate studies or jobs in the field have a solid background in the full range of electrical engineering, and we have found this to be a vital strength of our graduates.

Another mechanism for flexibility is that certain required courses may be exempted under certain limited conditions. The rules of the school have historically permitted a limited number of required courses to be substituted with other courses. This process is tightly controlled through the faculty advisement process. For example, although linear algebra (MA326) is listed as a required course for students in the signal processing and electronics tracks, a number of other math electives would be acceptable in its place, including discrete mathematics (MA352), complex analysis (MA345) and others. As another example, a student in the electronics track who presents a cohesive argument for substituting communication networks ECE103 with another course would be granted permission to do so.

This idea also works in reverse. Technically, a student following the signal processing path is not required to take the course in integrated circuit engineering (ECE341). However, all students in the path will be urged to seriously consider taking that course as an elective, because of its relevance to communication electronics and DSP. In the end, there must always be trade-offs in terms of which subjects are required in any curriculum.

It is important to point out that students are not locked into one track or another, and there is really no formal declaration process. The only formality is that the student must complete all the requirements of (at least) one track, perhaps with limited substitutions, to graduate. Thus, the multiple tracks really serve as an advisement tool, and foster thinking, planning and understanding of education plans by students, rather than as rigid, disparate and unrelated paths through the curriculum.

The last critical aspect to flexibility is the large number of elective credits, and a relatively free senior year. Students in signal processing and electronics tracks must take 15.5 elective credits in engineering or science (including math), and students in the computer engineering track must take 12.5 such credits. The elective choices are subject to faculty approval, and students will be expected to put some coherent thought into their study plans. That doesn't mean all the electives must for a cohesive concentration. Although that is certainly a possibility, a broad sampling of different topics, not just in electrical engineering, can also be valuable. The point is that thought and planning is expected.

The curriculum has been intentionally designed with a relatively light load in the senior year, necessary to arrive at the 135 credit requirement for the Bachelor's degree. First, it demonstrates to students that they can indeed complete all required courses in three years. It also enables students to take additional elective credits and either begin taking graduate level courses early, or simply graduate with a Bachelor's degree having taken more than 135 credits. It also enables students to put off certain courses from earlier years, to lighten their load, and make up the courses in the senior year. Another possibility is that some students may be so eager to specialize in a certain area that they may ask for permission to put off a required course and take an elective earlier. These strategic decisions can be made with faculty guidance.

One could argue that including slots for electives prior to the senior year in the curriculum would be desirable. In fact, that possibility does exist. First, a significant number of EE students receive Advance Placement credit for one or more core math or science courses. Second, as stated above, there are flexibilities in the sequencing of courses. Third, strong students are permitted to take an overload course each semester. In the end, taking one or more electives prior to the senior year will continue to be the norm rather than the exception.

The potentially open nature of the senior year serves the needs of the exceptional and advanced student as well as the weaker student. Moreover, it serves as an important motivational tool. The concept of a totally elective senior year (including freedom of choice for the non-technical electives, and freedom of choice in the capstone design project), even if in the end one or more required courses end up being taken that year, is a powerful one. Hopefully, this will inspire students to plan what they want to do in their last year of study, and then look beyond that year to either graduate studies or careers.

Dissemination and Informed Constituencies.

The curriculum development is an ongoing process. For example, data structures in the computer engineering track was split from what had been historically offered as a single elective course into two 2 credit courses (ECE164/165). Although several pedagogical benefits flow from this, the original reason to do this was to fit the quantum mechanics physics course (PH214) in that track. An original version of our curriculum had exempted students in the computer engineering track from taking PH214. This was quickly identified as a weakness and changes were made to accommodate keeping the course before the first generation of students reached that point.

As this process has unfolded and continues to evolve, it is vital to keep students informed. Support from the students and alumni for the changes to the curriculum is essential. Moreover, if we expect students to give serious thought to their study plans, they must be kept informed. The faculty have kept the students and alumni apprised of discussions and latest developments. A truly indispensable tool for this process has been the Department's web site, *http://www.ee.cooper.edu*. It not only presents the multi-track curriculum in tabular form, but also explains the principles behind the curriculum, and offers guidance to students in developing their plan. Students have also been given printed handouts, and notices are posted.

The web site also assists faculty in advising students. Many courses have changed, as have the list of requirements, and a central clearinghouse of information is absolutely necessary to prevent confusion. We have heavily publicized the site. In fact, we have a poster right in front of the elevators on the electrical engineering floor that gives the web address.

We also have made extensive efforts to inform alumni, employers, students, and prospective students visiting during open house of our curriculum development efforts. Informing constituencies and inviting feedback is part of the assessment process necessary for accreditation, and also helps us obtain buy-in from our constituencies.

Finally, we believe that the dissemination of the efforts we are undertaking, and the problems as well as the successes we will encounter, can assist other engineering schools in developing and deploying their own innovative curricula.

Table 1: Signal Processing & Communications Track

FIRST YEAR

FALL: 18

CH110	General Chemistry	3	
CS102	Intro Computer Science	3	
EID101	Engineering Design	3	***P***
MA110	Intro Linear Algebra	2	
MA111	Calculus I	4	
HSS1	Hum/Soc Sci Core I	3	
ESC000.1	Professional Devel Seminar I	0	

SPRING: 18.5

CH111	Chemistry Laboratory	1.5	
CH160	Physical Princ Chemistry	3	
ECE150	Digital Logic Design	3	***P***
MA113	Calculus II	4	
PH112	Physics I (Mechanics)	4	
HSS2	Hum/Soc Sci Core II	3	
ESC000.2	Professional Devel Seminar II	0	

SECOND YEAR

FALL: 16.5

ECE141	Circuits & Electronics I	3	
MA223	Vector Calculus	2	
MA240	Ord & Part Differential Eqns	3	
PH213	Physics II (Electromagnetics)	4	
PH291	Introductory Physics Lab	1.5	
HSS3	Hum/Soc Sci Core III	3	
ESC000.3	Professional Devel Seminar III	0	

SPRING: 17

ECE110	MATLAB: Sig & Sys	0	
ECE111	Signal Proc & Sys Analysis	3	***G***
ECE131	Solid-State Materials	3	
ECE151	Computer Architecture	3	***P***
MA224	Probability	2	
PH214	Physics III (Modern Physics)	3	
HSS4	Hum/Soc Sci Core IV	3	
ESC000.4	Professional Devel Seminar IV	0	

THIRD YEAR

FALL: 19.5

ECE101	Communication Theory	3	***C***
ECE114	Digital Signal Processing	3	***C***
ECE121	Control Systems	3	***C***
ECE142	Circuits & Electronics II	3	
ECE193	ECE Projects I	1.5	***P***
MA326	Linear Algebra	3	
Hum/SS	Hum/Soc Sci elective	3	

SPRING: 17

ECE103	Communication Networks	3	***C***
ECE135	Engineering Electromag	4	
ECE194	ECE Projects II	4	***P***
ECE302	Prob & Stochastic Proc	3	***C***
Hum/SS	Hum/Soc Sci elective	3	

FOURTH YEAR

FALL: 14

ECE195	ECE Projects III	4	***P***
	Non-technical elective	3	
Eng/Sci	Eng/Sci electives	7	
	*****Integrated Master Eng/Sci electives***	***6***	

SPRING: 14.5

ECE196	ECE Projects IV	3	***P***
	Non-technical elective	3	
Eng/Sci	Eng/Sci electives	8.5	
	*****Integrated Master Eng/Sci electives***	***3***	

FIFTH YEAR (MASTER'S)

FALL

ECE499	Thesis and/or Research	*3*
Eng/Sci	Eng/Sci Electives	*9*

SPRING

ECE499	Thesis and/or Research	*3*
Eng/Sci	Eng/Sci Electives	*6*

Requirements for Bachelor's Degree 135

Requirements for Master's Degree *165*

G: Gateway Course C: Concentration Course P: Projects Course

Table 2: Electronic Systems & Materials Track

FIRST YEAR

FALL: 18

CH110	General Chemistry	3	
CS102	Intro Computer Science	3	
EID101	Engineering Design	3	***P***
MA110	Intro Linear Algebra	2	
MA111	Calculus I	4	
HSS1	Hum/Soc Sci Core I	3	
ESC000.1	Professional Devel Seminar I	0	

SPRING: 18.5

CH111	Chemistry Laboratory	1.5	
CH160	Physical Princ Chemistry	3	
ECE150	Digital Logic Design	3	***P***
MA113	Calculus II	4	
PH112	Physics I (Mechanics)	4	
HSS2	Hum/Soc Sci Core II	3	
ESC000.2	Professional Devel Seminar II	0	

SECOND YEAR

FALL: 16.5

ECE141	Circuits & Electronics I	3	***G***
MA223	Vector Calculus	2	
MA240	Ord & Part Differential Eqns	3	
PH213	Physics II (Electromagnetics)	4	
PH291	Introductory Physics Lab	1.5	
HSS3	Hum/Soc Sci Core III	3	
ESC000.3	Professional Devel Seminar III	0	

SPRING: 17

ECE110	MATLAB: Sig & Sys	0	
ECE111	Signal Proc & Sys Analysis	3	
ECE131	Solid-State Materials	3	***C***
ECE151	Computer Architecture	3	***P***
MA224	Probability	2	
PH214	Physics III (Modern Physics)	3	***C***
HSS4	Hum/Soc Sci Core IV	3	
ESC000.4	Professional Devel Seminar IV	0	

THIRD YEAR

FALL: 19.5

ECE101	Communication Theory	3	
ECE114	Digital Signal Processing	3	
ECE121	Control Systems	3	
ECE142	Circuits & Electronics II	3	***C***
ECE193	ECE Projects I	1.5	***P***
MA326	Linear Algebra	3	
Hum/SS	Hum/Soc Sci elective	3	

SPRING: 17

ECE103	Communication Networks	3	
ECE135	Engineering Electromag	4	***C***
ECE194	ECE Projects II	4	***P***
ECE341	Integrated Circuit Eng	3	***C***
Hum/SS	Hum/Soc Sci elective	3	

FOURTH YEAR

FALL: 14

ECE195	ECE Projects III	4	***P***
	Non-technical elective	3	
Eng/Sci	Eng/Sci electives	7	

*****Integrated Master Eng/Sci electives 6***

SPRING: 14.5

ECE196	ECE Projects IV	3	***P***
	Non-technical elective	3	
Eng/Sci	Eng/Sci electives	8.5	

*****Integrated Master Eng/Sci electives 3***

FIFTH YEAR (MASTER'S)

FALL

ECE499	Thesis and/or Research	*3*
Eng/Sci	Eng/Sci Electives	*9*

SPRING

ECE499	Thesis and/or Research	*3*
Eng/Sci	Eng/Sci Electives	*6*

Requirements for Bachelor's Degree 135

Requirements for Master's Degree *165*

G: Gateway Course   C: Concentration Course   P: Projects Course

Table 3: Computer Engineering Track

FIRST YEAR

FALL: 18

CH110	General Chemistry	3	
CS102	Intro Computer Science	3	
EID101	Engineering Design	3	***P***
MA110	Intro Linear Algebra	2	
MA111	Calculus I	4	
HSS1	Hum/Soc Sci Core I	3	
ESC000.1	Professional Devel Seminar I	0	

SPRING: 18.5

CH111	Chemistry Laboratory	1.5	
CH160	Physical Princ Chemistry	3	
ECE150	Digital Logic Design	3	***G,P***
MA113	Calculus II	4	
PH112	Physics I (Mechanics)	4	
HSS2	Hum/Soc Sci Core II	3	
ESC000.2	Professional Devel Seminar II	0	

SECOND YEAR

FALL: 19.5

ECE141	Circuits & Electronics I	3	
ECE161	Programming Languages	3	***C***
MA223	Vector Calculus	2	
MA240	Ord & Part Differential Eqns	3	
PH213	Physics II (Electromagnetics)	4	
PH291	Introductory Physics Lab	1.5	
HSS3	Hum/Soc Sci Core III	3	
ESC000.3	Professional Devel Seminar III	0	

SPRING: 20

ECE110	MATLAB: Sig & Sys	0	
ECE111	Signal Proc & Sys Analysis	3	
ECE131	Solid-State Materials	3	
ECE151	Computer Architecture	3	***C,P***
ECE164	Data Struct & Algorithms I	2	***C***
MA224	Probability	2	
PH214	Physics III (Modern Physics)	3	
HSS4	Hum/Soc Sci Core IV	3	
ESC000.4	Professional Devel Seminar IV	0	

THIRD YEAR

FALL: 18.5

ECE101	Communication Theory	3	
ECE114	Digital Signal Processing	3	
ECE142	Circuits & Electronics II	3	
ECE165	Data Struct & Algorithms II	2	***C***
ECE193	ECE Projects I	1.5	***P***
MA352	Discrete Mathematics	3	***C***
Hum/SS	Hum/Soc Sci elective	3	

SPRING: 16

ECE103	Communication Networks	3	
ECE194	ECE Projects II	4	***P***
ECE302	Prob & Stochastic Proc	3	
ECE361	Software Eng & Large Sys	3	***C***
Hum/SS	Hum/Soc Sci elective	3	

FOURTH YEAR

FALL: 13

ECE195	ECE Projects III	4	***P***
	Non-technical elective	3	
Eng/Sci	Eng/Sci electives	6	
*****Integrated Master Eng/Sci electives***		***6***	

SPRING: 12.5

ECE196	ECE Projects IV	3	***P***
	Non-technical elective	3	
Eng/Sci	Eng/Sci electives	6.5	
*****Integrated Master Eng/Sci electives***		***3***	

FIFTH YEAR (MASTER'S)

FALL

ECE499	Thesis and/or Research	*3*
Eng/Sci	Eng/Sci Electives	*9*

SPRING

ECE499	Thesis and/or Research	*3*
Eng/Sci	Eng/Sci Electives	*6*

Requirements for Bachelor's Degree 135

Requirements for Master's Degree *165*

G: Gateway Course C: Concentration Course P: Projects Course

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