The University of Connecticut

School of Engineering

BIOMEDICAL ENGINEERING

GUIDE TO COURSE SELECTION

AY 2006-2007

for

Biomedical Engineering (BME) Majors

in the School of Engineering

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1. INTRODUCTION

The purpose of this document is to guide students in designing a plan of study for the Biomedical Engineering program at the University of Connecticut (UConn). Any such plan must be consistent with the Biomedical Engineering Program Educational Objectives. The Program Educational Objectives have been developed to satisfy the requirements of ABET and the general education requirements of UConn. For Biomedical Engineering, ABET curricular requirements are given as:

> "The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program.
>
> The program must demonstrate that graduates have: an understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology; the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems."

The Biomedical Engineering curriculum allows for the choice of several senior-level courses. This makes it possible for students to specialize in one of the following tracks: Biochemical Engineering, Biofluid Biomechanics, Bioinformatics, Bioinstrumentation, Biomaterials, and Biosolid Biomechanics. This Guide is intended to be used in conjunction with the University of Connecticut General Catalog as a source of information regarding degree requirements in Biomedical Engineering.

1.1 Preparation of Plans of Study

Prior to registration during the first semester of the Junior year, or for transfer students in the second semester at the University of Connecticut, whichever is later, each student must complete a Plan of Study form documenting the program he or she intends to follow. The BME Program Director is available to help students in developing a suitable Plan of Study form which is consistent with the Biomedical Engineering Program Educational Objectives.

2. BIOMEDICAL ENGINEERING PROGRAM

The Biomedical Engineering Program at the University of Connecticut is continuously evolving and improving in response to feedback from our constituents and program assessment results. We have developed a set of Program Educational Objectives which are periodically reviewed by all constituents (BME students, BME faculty, alumni, and employers). The feedback provided by our constituents is used to continuously refine and improve the Program Educational Objectives.

We have determined a set of Program Outcomes which are necessary for the achievement of the Program Educational Objectives. We use several assessment tools (employer surveys, alumni surveys, exit interviews, senior surveys, and course assessment surveys) to measure our success with respect to the Program Outcomes. The assessment results are reviewed periodically and used for the continuous improvement of the program and our courses.

The two-loop process involving the definition of the Program Educational Objectives (loop one) and the assessment / program improvement (loop two) is shown below.

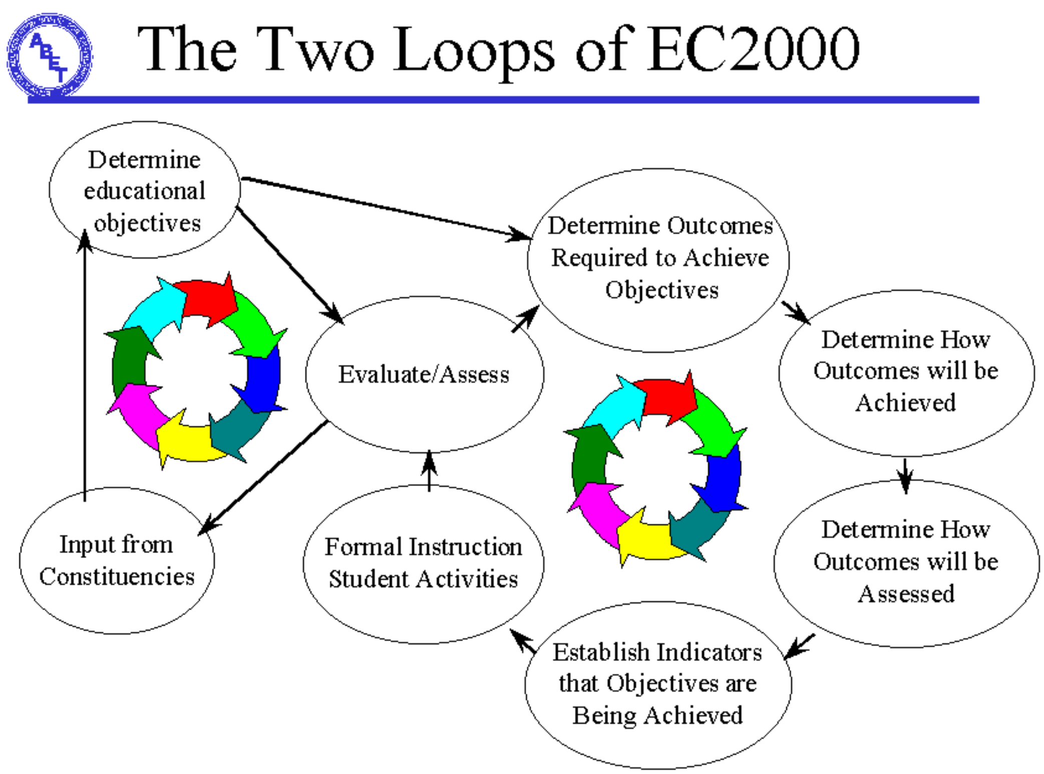

Figure 2.1. The two-loop process of Engineering Criteria 2000, as defined by the Accreditation Board for Engineering and Technology.

2.1 Biomedical Engineering Program Educational Objectives

Following the mission of the University and the School, the Biomedical Engineering program is committed to excel in teaching and research. The BME Program Educational Objectives and Program Outcomes are listed below:

Educational Objectives

Educational Objectives describe the performance of our alumni. The BME undergraduate Program Educational Objectives are that our alumni:

- are equipped with an up-to-date technical and hands-on education in biomedical engineering emphasizing analysis, synthesis and design, allowing them to successfully work in industry, or attend graduate, medical, dental, business or law schools.
- possess a desire for life-long learning and a curiosity about the world.
- Possess the quantitative and analytic skills necessary to embrace emerging technologies and the ability to look at traditional textbook learning with a fresh perspective.
- possess excellent written and oral communication skills necessary to interact with health care professionals, engineers and scientists.
- possess the ability to work effectively in teams.
- possess the sense of responsibility of a professional engineer.
- will become global leaders in the biomedical engineering professions.

Program Outcomes

Program Outcomes describe the performance of our students at the time of graduation. The BME program has demonstrated that our students have attained:

A. an ability to apply knowledge of mathematics, science, and engineering in the solution of biomedical engineering problems

B. an ability to design and conduct experiments, as well as to analyze and interpret data

C. an ability to design a biomedical engineering system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

D. an ability to function on multi-disciplinary teams including working on a biomedical engineering senior design project

E. an ability to identify, formulate, and solve engineering problems

F. an understanding of professional and ethical responsibility

G. an ability to communicate effectively

H. the broad education necessary to understand the impact of engineering solutions in a global and societal context

I. a recognition of the need for, and an ability to engage in life-long learning

J. a knowledge of contemporary issues

K. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

L. an understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology

M. an ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems

N. twenty-five percent of BME majors participate in study abroad

The Biomedical Engineering Curriculum described in section 3 has been designed to achieve the Program Educational Objectives and Program Outcomes.

3. BIOMEDICAL ENGINEERING CURRICULUM

The basic level curriculum has been designed to achieve the Program Educational Objectives and Program Outcomes, and to meet the University General Education Requirements. Section 3.1 describes the University General Education Requirements. Section 3.2 describes the basic-level Biomedical Engineering Curriculum, and Section 3.3 describes areas of specialization within Biomedical Engineering.

3.1 General Education Requirements (University Core Curriculum)

As part of all baccalaureate degree programs at the University, students are required to satisfy a common core of coursework known as the General Education Requirements. All students are required to take ENGL 110 or 111, or 250, or 105 and 109 (plus two "W" Courses). In addition, there is a foreign language requirement.

Foreign Languages

The minimum requirement is met if the student is admitted to the University with three years of a single foreign language in high school, or the equivalent. If the student has not met the minimum requirement through high school coursework, he or she must complete a two semester course sequence in a language at the University.

The General Education Requirements comprise four Content Areas. The Content Area courses in Groups One, Two, and Three must be taken in six different academic units. Content Area Three is automatically satisfied in the basic BME program of study. The others are summarized as follows:

Content Area One. Arts and Humanities. Six Credits

Arts and Humanities courses should provide a broad vision of artistic and humanist themes. These courses should enable students themselves to study and understand the artistic, cultural and historical processes of humanity. They should encourage students to explore their own traditions and their places within the larger world so that they, as informed citizens, may participate more fully in the rich diversity of human languages and cultures.

Content Area Two. Social Sciences. Six Credits

The social sciences examine how individuals, groups, institutions, and societies behave and influence one another and the natural environment. Courses in this group enable students to analyze and understand interactions of the numerous social factors that influence behavior at the individual, cultural, societal, national, or international level. They use the methods and theories of social science inquiry to develop critical thought about current social issues and problems.

Content Area Four. Diversity and Multiculturalism. Six Credits

In this interconnected global community, individuals of any profession need to be able to understand, appreciate, and function in cultures other than their own. Diversity and multiculturalism in the university curriculum contribute to this essential aspect of education by bringing to the fore the historical truths about different cultural perspectives, especially those of groups that traditionally have been under-represented. These groups might be characterized by such features as race, ethnicity, gender, sexual identities, political systems, or religious traditions, or by persons with disabilities. By studying the ideas, history, values, and creative expressions of diverse groups, students gain appreciation for differences as well as commonalities among people.

Subject matter alone cannot define multicultural education. A key element is to examine the subject from the perspective of the group that generates the culture. The inquiry needs to be structured by the concepts, ideas, beliefs, and/or values of the culture under study. A variety of approaches can be used, including comparative or interdisciplinary methodologies. Regardless of the approach, courses should view the studied group(s) as authors and agents in the making of history.

3.2 Overview of the Curriculum

The lower division or freshman and sophomore years of the Biomedical Engineering curriculum are similar to the other engineering curricula with the addition of Biology 107 in the second semester. The entire program of professional requirements is selected by the student, subject to approval by his/her advisor, the Department Head and final approval by the SoE Dean of Undergraduate Education. The recommended sequence of courses is as follows.

Bachelor of Science in Engineering in Biomedical Engineering

Freshman Year (Total credits: 33)

First Semester

CHEM 127 Q – General Chemistry (4 credits)
MATH 115Q - Calculus I (4 credits)
CSE 123C - Introduction to Computing (2 credits)
ENGL 110 or 111 – Seminar in Academic Writing or Seminar in Writing Through Literature (4 credits)
ENGR 100 - Orientation to Engineering (1 credit)
Category 1 (Not in PHIL)

Second Semester

CHEM 128Q - General Chemistry (4 credits)
MATH 116Q - Calculus II (4 credits)
BIOL 107 - Principles of Biology (4 credits)
ENGR 166 - Foundations Of Engineering (3 credits)

Sophomore Year (Total credits: 34)

First Semester

PHYS 151Q - Physics for Engineers I (4 credits)
MATH 210Q - Multivariable Calculus (4 credits)
CE 211 - Applied Mechanics I (3 credits)
BME 211 - Intro to Biomedical Engineering (3 credits)
Category 2 (Social Sciences)

Second Semester

PHYS 152Q - Physics for Engineers II (4 credits)
MATH 211 - Elementary Diff. Eq. (3 credits)
BME 251 - Biosystem Analysis (3 credits)
ECE 210W – Electric Circuits (4 credits)
PHIL 104 - Philosophy & Ethics (3 credits)

Junior Year (Total credits: 31)

First Semester

BME 252 - Biomedical Engineering Measurements (4 credits)
BME 261W - Biomechanics (4 credits)
PNB 264 - Human Physiology and Anatomy (4 credits)
CHEM 243 - Organic Chemistry (3 credits)
MMAT 201 or 243 - Material Science & Engr. I (3 credits)

Second Semester

BME 271 - Biomaterials (4 credits)
Engineering Elective (3 credits)
Life Science Elective (3 credits)
STAT 220Q - Statistical Methods (Calculus Level) (3 credits)

Senior Year (Total credits: 30)

First Semester

BME 221 - Biochemical. Engineering (3 credits)
BME 290 - Biomedical Engineering Design I (3 credits)
Biomedical Engineering Elective (3 credits)
Engineering Elective (3 credits)
Category 2 (Social Sciences; not same department as in Sophomore Year) (3 credits)

Second Semester

BME 291 - Biomedical Engineering Design II (3 credits)
Biomedical Engineering Elective (3 credits)
Engineering Elective (3 credits)
Category 4 (Diversity) (3 credits)
Category 4 (Multiculturalism) (3 credits)

TOTAL CREDITS FOR DEGREE: 128

4. TRACKS IN BME

In order to provide guidance for those students seeking to specialize in a subfield within Biomedical Engineering, six tracks of specialization associated with Biomedical Engineering have been identified which accommodate most student interests. These are:

1. Biochemical Engineering
2. Biofluid Biomechanics
3. Bioinformatics
4. Bioinstrumentation
5. Biomaterials
6. Biosolid Biomechanics.

Suggested courses for the unspecified Engineering Elective courses are presented in section 4.1. For information about tracks within Biomedical Engineering, the student may wish to examine the textbook *Introduction to Biomedical Engineering* used in BME 211, or issues of the *EMB Magazine* or view the UConn BME Program website, or the websites of the Biomedical Engineering professional societies IEEE *Engineering in Medicine and Biology Society* (http://www.ewh.ieee.org/soc/embs/) and http://EMB-Magazine.bme.uconn.edu or the *Biomedical Engineering Society* (http://www.bmes.org). In addition to the required BME courses, students also must two BME elective courses described in section 4.2. In addition to the required life science courses, one elective life science course is also required from the approved list in section 4.3.

4.1 Engineering Elective Courses

Must be a series of courses within a track. The purpose of the course selection is to develop an expertise within a traditional engineering program. A minimum total of 9 credit hours is required.

Biochemical Engineering Track

Biochemical engineering involves biotechnology and processes that convert natural materials such as sugars into molecules such as therapeutic proteins, and harnessing the synthetic capabilities of cells and genetic engineering.

CHEG 203 Introduction to Chemical Engineering
First Semester. Three credits. Recommended preparation: CHEM 128, MATH 114 or MATH 116, ENGR 150 or CSE 110 or CSE 123C. Open to sophomores.
Application of the principles of chemistry and physics to chemical processes; units, dimensions, and process variables; material balances; equations of state (ideal and real); single component equilibria; energy balances; non-reactive and reactive processes; combined mass and energy balances.

CHEG 211-212 Chemical Engineering Thermodynamics
Both Semesters. Three credits. Three class periods and one discussion period. Recommended preparation: MATH 210 and 211, CHEM 128, and CHEG 203 (or consent of Chemical Engineering Department Head). CHEG 211 and ME 233 may not both be taken for credit. CHEG 211 is open to sophomores. Consent of instructor and department head.
First Semester: first and second law of thermodynamics; thermal and PVT properties of matter; exact differentials and thermodynamic identities; design and analysis of power cycles; analysis of refrigeration and liquefaction processes.
Second Semester: properties of ideal and non-ideal mixtures; ideal and non-ideal phase equilibria; design of equilibrium flash separators; phase equilibria using equations of state; chemical equilibria; optimum condition for feasible reaction equilibria; of equipment and flow sheets; design and analysis of complete process plants.

CHEG 223 Transfer Operations
Both Semesters. Three credits. Three class periods and one discussion period. Prerequisite: MATH 210 and 211, CHEM 128, and CHEG 203 (or consent of Chemical Engineering Department Head).
Overall mass, energy, and momentum balances; fluid flow phenomena; theoretical and empirical relationships for design of incompressible fluid-flow systems; conductive heat transfer; heat transfer coefficients and design of heat exchange systems.

CHEG 251 Process Kinetics
Second Semester. Three credits. Recommended preparation: CHEG 212.
Theory of chemical reaction rate; homogeneous, heterogeneous and catalytic systems. Analysis and design of batch and flow reaction systems; analysis of rate data; temperature and catalytic effects in reactor design; mass transport effects; non-ideal reactor design.

Biofluid Biomechanics Track I
Biofluid biomechanics deals with the properties and movement of fluids under the influence of a force. A typical focus is the cardiovascular system and blood’s flow properties. Biomechanical engineers also study the flow of fluids in the body and the transfer of chemical substances across membranes and synthetic materials.

CE 212 Applied Mechanics II
Either Semester. Three credits. Not open to students who have passed CE 215. Prerequisite: CE 211, MATH 210. This course and CE 213 may not both be taken for credit. Open to sophomores.
Fundamentals of dynamics using vector methods. Rectilinear and curvilinear motion, translation, rotation, plane motion; work, energy and power; impulse and momentum. Computer applications.

CE 287 Mechanics of Materials
Either Semester. Three credits. Prerequisite ENGR 150 or CSE 110, CE 211 or CE 214 and CE 215, which may be taken concurrently. Open to sophomores.

Simple and combined stress, torsion, flexure and deflection of beams, continuous and restrained beams, combined axial and bending loads, columns. Computer applications.

CE 289 Intermediate Mechanics of Materials
Second Semester. Three credits. Prerequisite: CE 287. This course and ME 229 may not both be taken for credit.
Stresses and strains, curved beams, torsion of non-circular sections, flat plates, strain-energy, deflections. Impact and energy loads, repeated stress, mechanical properties of materials and theories of failure, influence of stress concentration.

OR

ME 229 Machine Design
Second Semester. Three credits. Prerequisite: CE 287. This course and CE 289 may not both be taken for credit.
Torsion of machine members with noncircular cross sections. Elastic stability and buckling. General methodology of stress analysis. Introduction to the theory of elasticity. Beams on elastic foundation. The energy method.

CE 297 Fluid Mechanics
Either Semester. Three credits. Prerequisite: CE 212 or CE 215, which may be taken concurrently, and MATH 210 and 211. This course and ME 250 may not both be taken for credit.
Statics of fluids, analysis of fluid flow using principles of mass, momentum and energy conservation from a differential and control volume approach. Dimensional analysis. Application to pipe flow and open channel flow. (Cross-listed with ME 250)

OR

ME 250 Fluid Dynamics I
Second Semester. Three credits. Prerequisite: ME 205 and 233, and MATH 210 and 211. This course and CE 297 may not both be taken for credit.
The laws of conservation of mass, momentum, and energy in fluid systems. Potential flow, boundary layers, introduction of compressible flow. (Cross-listed with CE 297)
Biofluid Biomechanics Track II

CE 212 Applied Mechanics II
Either Semester. Three credits. Not open to students who have passed CE 215. Prerequisite: CE 211, MATH 210. This course and CE 213 may not both be taken for credit. Open to sophomores.
Fundamentals of dynamics using vector methods. Rectilinear and curvilinear motion, translation, rotation, plane motion; work, energy and power; impulse and momentum. Computer applications.

ME 233 Thermodynamic Principles

Second Semester. Three credits. Prerequisite: CHEM 127Q, PHYS 151Q and MATH 210Q and 211Q which may be taken concurrently. Open to sophomores.
Introduction to the First and Second Laws of Thermodynamics. Thermodynamic properties of pure substances and ideal gases. Analysis of ideal and real processes - including turbines, pumps, heat exchangers, and compressors.

ME 242 Heat Transfer
First Semester. Three credits. Prerequisite: ME 233 and 250.
A study of the fundamental laws of conduction, convection and radiation of thermal energy and of mass transfer. Application of the general laws of heat transfer, and heat exchange to heat exchangers and insulation. The analytical, numerical, and graphical solution of one, two, and three dimensional problems.

ME 250 Fluid Dynamics I
Second Semester. Three credits. Prerequisite: ME 205 and 233, and MATH 210 and 211. This course and CE 297 may not both be taken for credit.
The laws of conservation of mass, momentum, and energy in fluid systems. Potential flow, boundary layers, introduction of compressible flow. (Cross-listed with CE 297)

CE 297 Fluid Mechanics
Either Semester. Three credits. Prerequisite: CE 212 or CE 215, which may be taken concurrently, and MATH 210 and 211. This course and ME 250 may not both be taken for credit.
Statics of fluids, analysis of fluid flow using principles of mass, momentum and energy conservation from a differential and control volume approach. Dimensional analysis. Application to pipe flow and open channel flow. (Cross-listed with ME 250)

Bioinformatics Track

Bioinformatics involves developing and using computer tools to collect and analyze data related to medicine and biology. Work in bioinformatics may involve using sophisticated techniques to manage and search databases of gene sequences that contain many millions of entries.

CSE 124C Computing
Second Semester. Four credits. Three class periods of lecture and one one-hour laboratory per week. Prerequisite: CSE 123C or CSE 110C. Not open for credit to students who have passed CSE 111 or CSE 130C.
Principles of object oriented programming including polymorphism, information hiding, and inheritance. Principles of object oriented design. Recursion. Strings, lists, stacks, queues, trees, priority queues, heaps and graphs including their use and various implementations using automatic and dynamic data allocation, linked representations, and templates. Algorithm and complexity issues involved with these data types. Sorting and searching algorithms. Introduction to computer history. Programming problems drawn from areas of computer science and engineering.

CSE 133 Object Oriented Design and Programming
Second semester. Three credits. Three class periods of lecture and one 75 minute laboratory period per week. Prerequisite: CSE 123C or 110C. Not open to students who have passed CSE 124C.
Principles of object oriented programming including classes, polymorphism, encapsulation and information hiding, and inheritance. Principles of object oriented design. Program debugging and documentation techniques. Implementation and simple analysis of algorithms for sorting and searching. Event-driven programming and the use of libraries for user interfaces. Introduction to computer history. Programming assignments.

CSE 134 Data Structures and Introduction to Algorithms
First semester. Three credits. Three class periods of lecture. Prerequisite: CSE 133 or 124C. Students who have passed CSE 124C will receive only 2 credits for this course.
Fundamental concepts of data structures and the algorithms that proceed from them. Implementation and use of linked lists, stacks, queues, trees, priority queues, heaps and graphs. Emphasis on recursion, abstract data types, object oriented design, and associated algorithms and complexity issues. Design using specifications and requirements. Basic computer organizations, including memory organizations and allocations issues. Programming assignments.

CSE 207 Digital Logic
Either Semester. Three credits. Three class periods and one one-hour discussion period. Required preparation: CSE 110C or 123C or 130C. Open to sophomores.
Representation of digital information. Introduction to the analysis and design of combinational and sequential logic networks using Boolean algebra and register transfer techniques. Structure and operation of digital systems and computers. Introduction to programming at the machine and assembler language level. Design projects.

CSE 208W Logic Design Laboratory
Either Semester. Two credits. One one-hour lecture and one two-hour laboratory period. Prerequisite: Secondary school physics or PHYS 101, and CSE 207 which may be taken concurrently. Open to sophomores.
Design and evaluation of combinational and sequential logic circuits. Debugging techniques. Use of computer facilities for circuit simulation, CAD and report preparation and presentation.

CSE 210W. Digital Logic Design
First semester. Four credits. Three class periods and one two-hour laboratory period. Prerequisite: CSE 110 or 123 or 130 or 133 and secondary school physics or PHYS 101 or 151; ENGL 105 or 110 or 111 or 250. Not open to students who have passed CSE 207 or 208W. Open to sophomores or higher.
Representation of digital information. Analysis, design, and evaluation of combinational and sequential logic circuits. Debugging techniques. Use of computer facilities for circuit simulation, CAD, and report preparation and presentation. Introduction to structure and operation of digital computers. Design projects. Written reports with revisions are required for each project.

CSE 220. Introduction to Computer Architecture
Either semester. Three credits. Three one-hour lectures and one one-hour laboratory period. Prerequisite: CSE 134; CSE 254. Cannot be taken after CSE 249 or 261. This course and CSE 201 may not both be taken for credit. This course and CSE 243 may not both be taken for credit.
Structure and operation of digital systems and computers. Fundamentals of digital logic. Machine organization, control and data paths, instruction sets, and addressing modes. Integer and floating-point arithmetic, the memory hierarchy, the I/O subsystem. Assembly language and basic program organization, interrupts, I/O, and memory allocation.

CSE 221 Probabilistic Performance Analysis of Computer Systems
Either Semester. Three credits. Prerequisite: CSE 124C and one of STAT 220Q or 230Q or MATH 231Q.
Introduction to the probabilistic techniques which can be used to represent random processes in computer
systems. Markov processes, generating functions and their application to performance analysis. Models
which can be used to describe the probabilistic performance of digital systems.

CSE 243 Introduction to Computer Architecture and Hardware/Software Interface
Either Semester. Four credits. Three hours lecture and three hours laboratory. Prerequisite: CSE 210W, or CSE 207 and CSE 208W. Not open for credit to students who have credit for CSE 241.
An integrated introduction to computer organization and the hardware/software interface as seen at the assembly-language level. Topics included: basic machine organization; instruction sets and addressing modes; CPU design; the control path and microprogramming; FSM design; the data path; integer and floating-point arithmetic; busses; the memory hierarchy; the i/o subsystem; RISC architectures; pipelining; basic performance analysis; fundamentals of networking. Lab activities include (but are not limited to): basic assembly language programming on a CICS and RICS processor; processor benchmarking; use of cache; polled, interrupt driven and DMA I/O files; optimizing code.

CSE 245 Computer Networks and Data Communication
Semester by arrangement. Three credits. Prerequisite: CSE 221 which may be taken concurrently.
Introduction to computer networks and data communications. Network types, components and topology, protocol architecture, routing algorithms, and performance. Case studies including LAN and other architectures.

249. Computer Organization and Architecture
Either semester. Three credits. Three one-hour lectures. Prerequisite: CSE 210W; CSE 220. This course and CSE 243 may not both be taken for credit. Cannot be taken after CSE 261.
Organization and architecture of modern computer systems. Emphasis is on alternatives and advances to the basic Von Neumann architecture: topics such as pipelining, memory hierarchy

and management, multiprocessor and alternative architectures, reconfigurable hardware, and other techniques for performance enhancement.

CSE 254. Introduction to Discrete Systems
Either semester. Three credits. Prerequisite: CSE 111 or 124C or 130C or 133. Not open for credit to students who have passed MATH 214Q. Open to sophomores or higher.
Mathematical methods for characterizing and analyzing discrete systems. Modern algebraic concepts, logic theory, set theory, grammars and formal languages, and graph theory. Application to the analysis of computer systems and computational structures.

Bioinstrumentation Track

Bioinstrumentation uses electronics, measurement principles and techniques, and innovative biosensors to develop devices for monitoring, diagnosing, and treating diseases. Computers have become increasingly important in this area. They monitor the condition of patients during surgery or in intensive care. Computers also monitor healthy people in unusual environments, such as astronauts in space or underwater divers at great depths. Bioinstrumentation engineers develop and investigate many tools to detect, diagnose, and study biological conditions. For example, medical imaging systems apply energy, such as X rays, or sound waves, to the body to create detailed pictures of internal structures. Biosignal processing is used to detect, classify and analyze signals produced by the body, and are used in medical devices. Other devices, such as an implantable defibrillator act as a personal physician if a heart attack occurs, restoring normal heart function. Biomedical engineers have developed certain lasers and other devices to help treat disorders. Lasers, which produce narrow, powerful beams of light, make possible bloodless surgery on blood vessels, nerve fibers, retinas and corneas. Automated infusion pumps continuously deliver the drug insulin to diabetic patients.

204. Electronic Devices and Circuits
(Formerly offered as EE 204.) Either semester. Three credits. Prerequisite: ECE 201. This course and ECE 239 may not both be taken.
Physical electronics underlying the operation of modern solid-state devices. Diodes and diode circuits. The bipolar junction transistor and field-effect transistors. Models of transistors. Applications of transistors to integrated circuits such as operational amplifiers and logic gates.

ECE 205 Electromagnetic Fields and Applications
First Semester. Three credits. Prerequisite: PHYS 152 and MATH 210 and 211.
Application of electric and magnetic field theory to engineering problems involving conductors, dielectrics, semiconductors, magnetic materials, the motion of charged particles, and wave propagation. Relationship between fields and circuit parameters in the context of transmission lines and radiation.

ECE 212 Electronic Circuit Design and Analysis
Either Semester. Four credits. Prerequisite: ECE 201 and ECE 209W; or ECE 210. Three one-hour lectures and one two-hour laboratory.

Physical electronics underlying the operation of electronic devices. Diodes, diode models, and diode circuits. Transistors, transistor models, and transistor circuits. DC, small signal, and frequency analysis of transistor amplifiers. Compound transistor configurations. Computer analysis tools. Design projects are implemented and tested in the laboratory. Laboratory reports with revisions are required for each project.

ECE 215 Digital Integrated Circuits
Semester by arrangement. Three credits. Prerequisite: ECE 202 or 204 and CSE 210W or 207.
Basic concepts of circuit analysis as applied to electronic circuits and electromechanical devices, including measuring instruments.

ECE 228 Fiber Optics
First Semester. Three credits. Prerequisite: ECE 205 or ECE 207 or PHYS 255.
Application of Maxwell's equations and geometric optics first to two-dimensional dielectric waveguides and then to cylindrical fibers. Ray and mode theory, eigenvalues, Goos-Haenchen shift. Step-index, graded-index, and single-mode fibers. Splicers, couplers, sources, detectors and optical design. Fiber manufacturing techniques.

ECE 240 Electronic Circuits and Applications
Second Semester. Three credits. Prerequisite: ECE 204 and 232.
Analysis and design of control systems incorporating a digital computer as the controlling element. Building blocks of digital control. Measures of control system performance. Frequency domain and state variable methods of control design. Optimal control methods. State variable estimation. Implementation issues. Use of computer-aided software tools for simulation and design.

ECE 241 Communication Systems
First Semester. Three credits. Prerequisite: ECE 202, and STAT 224Q or consent of instructor.
Communication of information over noisy channels. Fourier transform review, spectral analysis, and sampling. Amplitude, phase, and frequency modulation of a sinusoidal carrier. Time and frequency division multiplexing. Random processes and analysis of communication of systems in noise. Elements of digital communication systems.

ECE 245 Micro/Opto-electronic Devices
Second Semester. Three credits. Prerequisite: ECE 204 or consent of instructor.
Principles and applications of contemporary solid state devices such as light-emitting diodes, injection lasers, solar cells, p-n-p-n diodes, SCR and Triacs, IMPATT diodes, Schottky devices, bipolar and MOS transistors, MESFETs and MODFETs, and fundamentals of integrated circuits.

ECE 266 Microprocessor Applications Laboratory
First Semester. Three credits. One class period and one four-hour laboratory.
Design of software and interface hardware to use a microcomputer as an on-line, real-time element in data acquisition, filtering and control systems. Use of clocks, DAC's, ADC's, speech

synthesis modules, and movement generators. Design project. Written and oral presentations of laboratory results

CSE 207 Digital Logic
Either Semester. Three credits. Three class periods and one one-hour discussion period. Required preparation: CSE 110C or 123C or 130C. Open to sophomores.
Representation of digital information. Introduction to the analysis and design of combinational and sequential logic networks using Boolean algebra and register transfer techniques. Structure and operation of digital systems and computers. Introduction to programming at the machine and assembler language level. Design projects.

CSE 208W Logic Design Laboratory
Either Semester. Two credits. One one-hour lecture and one two-hour laboratory period. Prerequisite: Secondary school physics or PHYS 101, and CSE 207 which may be taken concurrently. Open to sophomores.
Design and evaluation of combinational and sequential logic circuits. Debugging techniques. Use of computer facilities for circuit simulation, CAD and report preparation and presentation.

CSE 210W. Digital Logic Design
First semester. Four credits. Three class periods and one two-hour laboratory period. Prerequisite: CSE 110 or 123 or 130 or 133 and secondary school physics or PHYS 101 or 151; ENGL 105 or 110 or 111 or 250. Not open to students who have passed CSE 207 or 208W. Open to sophomores or higher.
Representation of digital information. Analysis, design, and evaluation of combinational and sequential logic circuits. Debugging techniques. Use of computer facilities for circuit simulation, CAD, and report preparation and presentation. Introduction to structure and operation of digital computers. Design projects. Written reports with revisions are required for each project.

Biomaterials Track

Biomaterials concern the development and selection of appropriate materials to place inside the human body. Such selection ranks among the most difficult tasks faced by biomedical engineers. It demands an understanding of the physical and chemical properties of the living tissue that a material will assist or replace. The material to be implanted must cause no harmful effects, such as poisonous reactions or cancer. In turn, the body must not damage the materials of the implant. For most devices implanted for a long period of time, the materials must be chemically inactive, durable enough to withstand the repeated stresses of a lifetime, and harmless to the tissues and blood. Implantable materials include certain ceramics, metal alloys, and plastics.

MMAT 202 Materials Science & Engineering Lab
Both Semesters. One credit. One three-hour laboratory period. Prerequisite: MMAT 201, which may be taken concurrently.

Illustrative experiments on microstructure, phase equilibria, heat treatment and mechanical properties.

MMAT 234 Materials Protection

Semester by arrangement. Three credits. Not open for credit to students who have passed MTGY 343.

Corrosion and materials protection designed for engineering students. Principles of materials degradation, extensive case histories and practical applications. Selection of metals, alloys, ceramics and polymers for atmospheric, soil, marine and chemical environments. Evaluation methods, protective measures and the techniques of failure analysis.

MMAT 236 Materials Characterization

Semester by arrangement. Three credits. Two class periods and, every other week, a three-hour laboratory period. Laboratory sections in addition to that listed in Directory of Classes will be arranged.

Principles and experimental methods of optical, electron, and x-ray examination of engineering materials. Emphasis on use of x-ray analysis, with introduction to electron microscopy, Auger spectroscopy, scanning electron microscopy, and microanalysis.

MMAT 244 Introduction to Structure, Properties, and Processing of Materials II

Second Semester. Three credits. Prerequisites: MMAT 243 or MMAT 201. Open to sophomores.

Principles underlying the selection of materials and the control of microstructure through processing will be introduced, with emphasis on injection molding, extrusion, casting, particulate processing, electrochemistry, corrosion, refining, vapor processing, processing-property relations.

MMAT 265 Structure-Property Relations I: Phase Transformation Kinetics and Applications

First Semester. Three credits. Prerequisite: PHYS 152Q. Co-requisite: MMAT 243 or MMAT 201.

Principles and applications of phase transformations to control microstructure and materials properties. In-depth, quantitative coverage will include atomic and molecular arrangements; lattices; point, line, and surface defects; cross links, entanglements, glasses, diffusion; kinetics of nucleation and growth; and thermal treatments to control microstructure.

MMAT 266 Structure-Property Relations II: Strengthening and Toughening Mechanisms

Second Semester. Three credits. Prerequisite: MMAT 265.

Principles and applications of strengthening and toughening mechanisms will be treated quantitatively with emphasis on line defects, microplasticity, displacive and diffusional transformations, fillers, sintering, creep, and creep rupture.

MMAT 284 Materials Processing Laboratory

Second Semester. One credit. Co-requisite: MMAT 244. One three-hour laboratory period. Open to sophomores.

Principles of materials processing will be illustrated by hands-on experience with qualitative and quantitative microscopy, testing, and reverse engineering, with experiments on polymer extrusion and injection molding, alloy casting, elutriation, particle compaction, sintering, forging, welding, and electrodeposition.

MMAT 286 Materials Characterization Laboratory II
Second Semester. One credit. Prerequisite: MMAT 265. One three-hour laboratory period.
Hands-on experience with materials characterization will be gained through workshops on X-ray fluorescence and diffraction, scanning electron microscopy, electronic and magnetic property measurement, and failure analysis.

CHEG 256 Polymeric Materials
Either Semester. Three credits. Recommended preparation: CHEM 244. Not open for credit to students who have passed CHEM 280.
Structure, properties, and chemistry of high polymers; solution and phase behavior; physical states, viscoelasticity and flow; production and polymer processing; design of polymers for specific applications.
Biosolid Biomechanics Track
Biomechanics is mechanics applied to biology. This includes the study of motion, material deformation, and fluid flow. For example, studies of the fluid dynamics involved in blood circulation have contributed to the development of artificial hearts, while an understanding of joint mechanics has contributed to the design of prosthetic limbs.

CE 212 Applied Mechanics II
Either Semester. Three credits. Not open to students who have passed CE 215. Prerequisite: CE 211, MATH 210. This course and CE 213 may not both be taken for credit. Open to sophomores.
Fundamentals of dynamics using vector methods. Rectilinear and curvilinear motion, translation, rotation, plane motion; work, energy and power; impulse and momentum. Computer applications.

ME 224 Analysis and Design of Mechanisms
First Semester. Three credits. Prerequisite: MATH 210 and 211 and CE 211.
Application of kinematics in the analysis and synthesis of mechanisms. Type and dimensional design of linkages, cams and gears based on motion requirements and kinetostatic force transmission, in contrast to the strength requirements. Graphical, analytical and computer methods in analysis and design of mechanisms. Design considerations in mechanism synthesis. Design project.

CE 287 Mechanics of Materials
Either Semester. Three credits. Prerequisite: CE 211 or CE 214. Open to sophomores.
Simple and combined stress, torsion, flexure and deflection of beams, continuous and restrained beams, combined axial and bending loads, columns. Computer applications.

ME 227 Design of Machine Elements
First Semester. Three credits. Prerequisite: ME 205 and CE 287.

Application of the fundamentals of engineering mechanics, materials and manufacturing to the design and analysis of machine elements.

ME 253 Linear Systems Theory
First Semester. Three credits. Prerequisite: CE 212 and MATH 211Q.
Mathematical modeling of dynamic systems, linearization of nonlinear behavior, Laplace domain representation of dynamics, transfer functions, block diagram algebra, signal-flow graphs, Mason's rule, transient analysis of system response, convolution integral, Duhamel's integral, Green's function, stability of linear systems, Routh-Hurwitz method, root locus, frequency response, Bode and polar representations, introduction to feedback systems.

4.2 Biomedical Engineering Elective Courses

A total of two different 3-credit courses is required and must be selected from the following four courses: BME 223, BME 253, 255, 272, 273 and 274.

BME 223 Fermentation and Separation Technologies Laboratory
Second Semester. Three credits. One class and two three-hour laboratories. Prerequisite: BME 221.
Introduction to techniques used for industrial mass culture of prokaryotic and eukaryotic cells, and methods used to extract useful products from these cultures. Metabolic processes, energentics, growth kinetics and nutrition of microorganisms. Synthesis of cellular material and end products. Heat exchange, oxygen transfer, pH control, sterilization and design of fermentors. Culture of eukaryotic cell mass. Immobilized enzyme and cell reactors. Product recovery methods of precipitation centrifugation, extraction filtration and chromatography.

BME 253 Physiological Control Systems
Semester by arrangement. Three credits. Prerequisite: BME 251 or ECE 232.
Analysis of human physiological control systems and regulators through the use of mathematical models. Identification and linearization of system components. Systems interactions, stability, noise, and the relation of system malfunction to disease. The analysis and design of feedback systems to control physiological states through the automatic administration of drugs.

BME 255 Bioinstrumentation
Either Semester. Three credits. Prerequisite: BME 252.
Modeling, analysis, design, and operation of transducers, sensors, and electrodes, for physiological systems; operational and instrumentation amplifiers for bioelectric event signal conditioning, interfacing and processing; A/D converters and hardware and software principles as related to sampling, storing, processing, and display of biosignals and digital computers.

BME 262 Biosolid Mechanics
Either Semester. Three credits. Prerequisite: BME 261W and CE 287.
Mechanical behavior of biological solids. Applications of the theories of elasticity,

viscoelasticity, and poroelasticity to bones, ligaments and tendons, skeletal muscle, and articular cartilage. Axial, bending, shearing and torsional loadings. Bone morphology and growth. Biphasic theory. Failure theories. Topics may be modified slightly to accommodate student interests.

BME 272 Advanced Biomaterials
Semester by arrangement. Three credits. Prerequisite: BME 211 and BME 271.
The strategies and fundamental bioengineering design criteria behind the development of cell-based tissue substitutes, artificial skin, muscle, tendons, bone, and extracorporeal systems that use either synthetic materials or hybrid (biological-synthetic) systems. Topics include biocompatibility, biological grafts, gene therapy-transfer, and bioreactors.

BME 273 Advanced Biomaterials
Semester by arrangement. Three credits. Prerequisite: BME 211 and BME 271.
The aim of the course is to gain in-depth knowledge of a series of biomaterials for various applications. This course will focus on a few topics, including calcium phosphates and composites for hard tissue replacement, drug delivery systems, issues unique to the biomedical field, and regulations for new products and standards. Not open to students who have passed BME 272. (This course replaced BME 272).

BME 274 Introduction to Tissue Engineering
Semester by arrangement. Three credits. Prerequisite: BME 271.
Presents basic principles of biological, medical, and material science as applied to implantable medical devices, drug delivery systems and artificial organs.

BME 280 Bioinformatics
Either Semester. Three credits. Prerequisite: BIOL 107, CSE 254 and either STAT 220Q or STAT 224Q.
Fundamental mathematical models and computational techniques in bioinformatics. Exact and approximate string matching, suffix trees, pairwise and multiple sequence alignment, Markov chains and hidden Markov models. Applications to sequence analysis, gene finding, database search, phylogenetic tree reconstruction. (Cross-listed with CSE 277.)

BME 295 Special Topics in Biomedical Engineering
Semester by arrangement. Credits by arrangement. Prerequisite: Announced separately for each course. With a change in content, this course may be repeated for credit. Classroom and/or laboratory courses in special topics as announced in advance for each semester.

BME 299 Independent Study in Biomedical Engineering
Semester by arrangement. Credits and hours by arrangement, not to exceed four in any semester. Prerequisite: Consent of instructor. With a change in content, this course may be repeated for credit.
Individual exploration of special topics as arranged by the student with an instructor of his or her choice.

4.3 Life Science Elective

Three-credit hours are required and must be from the following courses:

MCB 203. Introduction to Biochemistry
Either semester. Four credits. Three class periods and one 3-hour laboratory period. Prerequisite: CHEM 141 or 244. (CHEM 244 may also be corequisite.) Open to sophomores or higher. Not open for credit to students who have passed MCB 204.
The structure, chemistry, and metabolism of carbohydrates, lipids and proteins. Enzyme function and kinetics, energy metabolism, and structure and function of nucleic acids. A survey course for students of agriculture, general biology, medical technology, nursing, and pharmacy. Molecular and Cell Biology majors, biophysics majors, and other students desiring a more intensive introduction or considering advanced course work in biochemistry or molecular biology should take MCB 204. A fee of $20 is charged for this course.

MCB 204 Biochemistry
First Semester. Five credits. Four class periods and one three-hour laboratory. Recommended preparation: CHEM 244, which may be taken concurrently. Not open for credit to students who have passed MCB 203.
The structure and function of biological macromolecules. The metabolism of carbohydrates, lipids, amino acids, proteins and nucleic acids and its regulation. Energy metabolism. An in-depth introduction, designed for students planning to take advanced course work in biochemistry, biophysics, or other areas of molecular biology.

CHEM 240 Organic Chemistry Laboratory
Either Semester. One credit. One four-hour laboratory period. Not open for credit to students who have passed CHEM 245. Prerequisite: CHEM 243. This course is open only to Chemical Engineering or Biomedical Engineering majors or by consent of instructor. Open to sophomores or higher.
Introduction to techniques, manipulations, calculations and spectroscopy.

CHEM 244 Organic Chemistry
Either Semester. Three credits. Prerequisite: CHEM 243. Open to sophomores or higher.
A continuation of CHEM 243.

CHEM 263Q Physical Chemistry
Both Semesters. Four credits each semester. Prerequisite: CHEM 128 or 130 or 138 or 152 or 154; PHYS 123, or 132, or 142, or 152; MATH 210 or 220.
A study of gases, liquids, solids, solutions, and thermodynamics in CHEM 263 and kinetics, atomic and molecular theory and spectroscopy in CHEM 264.

MCB 229 Fundamentals of Microbiology
Either Semester. Four credits. Three lecture periods and one 2-1/2-hour laboratory period. Prerequisite: CHEM 141 or 243 (either may be taken concurrently). Recommended preparation: BIOL 107 or equivalent. Open to sophomores.

Biology of microorganisms, especially bacteria. Cellular structure, physiology, genetics, and interactions with higher forms of life. Laboratory familiarizes students with methodology of microbiology and aseptic techniques.

MCB 232C Microcomputer Applications in Molecular & Cell Biology
First Semester. Three credits. One one-hour lecture and two three-hour laboratories.
Recommended preparation: MCB 200 or 204 or 210 or 213 or 229.
Introduction to the use of microcomputers in molecular biology, emphasizing commercially available applications software, both general (spreadsheet, word processing, database, graphics) and specialized (DNA and protein sequence database manipulation, molecular modeling, data acquisition, others).

PNB 265 Human Physiology & Anatomy II
Both Semesters. Four credits each semester. Three class periods and one three-hour laboratory. Prerequisite: CHEM 122Q or 127Q. Recommended preparation: BIOL 107, PHYS 101 or 122. Open to sophomores. Not open to students who have passed PNB 274-275. These courses must be taken in sequence to obtain credit, and may not be counted toward the Biological Sciences or Physiology and Neurobiology majors.
Fundamentals of human anatomy and physiology for students in medical technology, physical therapy, nursing, and education (Sport Science).

4.4 Double Majors, Minors and Additional Degrees

Opportunities exist to pursue a double major program in Biomedical Engineering and one of the other undergraduate engineering curricula, to pursue a minor degree program in conjunction with the BME degree, or to pursue an additional degree within the University.

Double Major with another Engineering program

Opportunities exist to pursue a double major program in Biomedical Engineering and one of the other undergraduate engineering curricula. If a student wishes to be a double major within Engineering, he or she should notify the Dean of Undergraduate Education. Careful planning of course selection should be done each semester in consultation with the student's advisor. A separate Plan of Study form for each major must be prepared and submitted for approval.

Minors

Several minors are available within the University that may be attractive to students pursuing the Biomedical Engineering degree. These are listed in the General Catalog.

Additional Degree with another major outside of Engineering

From time to time students wish to obtain an additional degree in a field outside of the School of Engineering. One example of an additional degree would be that found in the EUROTECH program in which the completion of a degree in German Studies within the College of Liberal Arts & Sciences is achieved at the same time the student completes the primary degree in a major within the School of Engineering. In addition, a student may pursue a double major in BME other foreign languages. This is an excellent combination with study abroad in biomedical engineering. Students who have such an interest should discuss the procedure for pursuing the additional degree with the Director of Undergraduate Advising, (486-5462), Undergraduate Programs Office.

5. FILLING OUT THE PLAN OF STUDY FORM

All students in the first semester of their Junior year in the Engineering curriculum must prepare a written Plan of Study form. These students should work with their advisors to determine a Plan of Study which meets the degree requirements of the School of Engineering and the University.

After an initial consultation with the advisor, the student should prepare two (2) original copies of the Plan of Study form (available from the BME Program Director's office) by following the guidelines given below. Once the two original copies are prepared, the student should make an appointment with his or her advisor to have him/her review and approve the form. Both the advisor and the student should check his or her transcript to be sure that all Lower Division (freshman/sophomore) requirements have been met and should check that the proposed Upper Division (junior/senior) plan satisfies Department, School and University requirements. After the form is approved by the advisor, the two originals should be forwarded to the BME Program Director, Prof. John Enderle, for approval, prior to being forwarded to the Director of Undergraduate Advising, Prof. David Jordan. Note: the student should check back with his or her advisor to see if any corrections must be made after the form has been reviewed by the BME Program Director.

The BME Program Director will evaluate and indicate approval of the Plan of Study, and then will send the two originals to the Director of Undergraduate Advising. The Director of Undergraduate Advising will evaluate the Plan and indicate his approval of it. In the event that approval is not given, the difference of opinion must be worked out among the advisor, the student and the Director of Undergraduate Advising or BME Program Director, as appropriate.

The Dean's Office will return two copies of the approved tentative Plan of Study form to the advisor: one of the two "originals" which is to be kept in the student's counseling folder, the other being a photocopy to be given to the student.

Note that an approved Plan of Study form can be modified at any time if course offerings and student objectives warrant it. However, no modification that jeopardizes the meeting of requirements will be approved. Modification must be made in consultation with the student's advisor and will usually involve the submission of a "revised" Plan of Study form for approval, in the same manner as the "original" form was prepared and submitted. Although not required until the last semester, it is suggested that a "revised" form be submitted each semester rather than waiting until the final semester. This way any problems can be caught as early as possible. This "revised" Plan of Study form may be created as done initially by forming two new originals, or by marking the changes on the approved "original" and having this "revised" form circulated for approval. Alterations to the courses listed should be made by crossing out the course(s) not taken, writing in those that were, and having the advisor initial and date each change. If extensive changes are to be made, or if a second revision is necessary, a new "original" Plan of Study form must be submitted.

The Plan of Study form should be reviewed at each subsequent registration period. ***In the student's last semester, he or she is required to file a "final" Plan of Study form which accurately lists all the courses that were taken to satisfy degree requirements.*** Any modifications to an already approved Plan of Study form should then be submitted for final approval following the above procedure.

The BME Office will generate a Plan of Study for you, or you can fill it out neatly in ink. All approval initials and signatures should also be in ink and dated. Expected date of graduation and year of catalog requirements must be clearly shown. The following guidelines should be adhered to:

Catalog year and date of graduation: It is extremely important that you accurately list what catalog year you are filing under and your intended date of graduation. Both items are needed for use by the Registrar so that completion of your degree requirements may be certified by your graduation date. The catalog year may be any year to the most recent continuous period of registration as an engineering student.

Courses taken: The Plan of Study form must show exactly the courses being used to satisfy degree requirements. Exemption from specific School of Engineering course requirements or substitution of alternative courses must be clearly indicated on the Plan of Study form, explained in the "Comments" section and/or with an attachment, and may require approval via petition by the Director of Undergraduate Advising (see "Exemption and Substitution" below).

Content Area Groups

Content Area One: Six credit hours are required in Content Area One. One of the courses is PHIL 104. The other one must be in a different department from the approved list.

Content Area Two: Six credit hours in different departments from the approved list are required in Content Area Two, from different departments than in Content Area One.

Content Area Three: Students in BME are required to take CHEM 127Q, 128Q; PHYS 151Q, 152Q, which automatically satisfy Content Area Three.

Content Area Four: Six credit hours from the approved list are required in Content Area Four. One Content Area 4 course must be an international course. One course may count as both Content Area 4 and Content Area 1 or 2.

Competencies

Foreign Language Requirement: The Foreign Language requirement calls for three years of a single foreign language in High School or a two semester course sequence in a language at the University. The words "High School" should be circled if the student has met this requirement in High School or by certification of English as a second language. If not, the appropriate courses should be listed with the credit by category columns modified accordingly (see "Credit Summary" below). Elementary levels of a foreign language should fall under the "Other" category, while more advanced language courses may be counted as "Humanities" credits in the ABET categories.

Information Literacy Requirement: Information literacy involves a general understanding of how information is created, disseminated and organized, and an ability to access, evaluate, synthesize and incorporate information into written, oral, or media presentations. Basic information literacy is taught to all freshmen as an integral part of ENGL 110/111, in collaboration with the staff of the University Libraries. Each major program has considered the information literacy competencies required of its graduates and built those expectations into the upper-level research and writing requirements in the major. Further details are given under the description of each major elsewhere in this catalog.

Quantitative Requirement: Students in Engineering are required to complete MATH 115Q, 116Q, 210Q, and 211Q which also satisfy the General Education Requirement for quantitative (Q) courses. (Note that MATH 112Q-113Q-114Q may be used to meet the freshman year calculus requirement.) I

Computer Technology: Entering students are expected to have the basic computer technology skills required to begin university study. CSE 123 satisfies this requirement.

Writing (W) Competency: All students must take either ENGL 110 or 111. Students passing ENGL 250 are considered to have met the ENGL 110 or 111 requirement. Additionally, all students must take two writing-intensive (W) courses, which may also satisfy Content Area requirements. One of these must be at the 200-level and associated with the student's major. Approved courses for each major are listed in their sections of this catalog. (Note: ENGL 110 or 111 is a prerequisite to all writing-intensive courses.) ECE 210W and BME 261W, required course in the BME program, satisfy this requirement.

Required courses: Required courses are shown on the form. If there are alternatives listed, the course(s) that the student has taken or intends to take should be circled. The credit by category columns should be modified as needed (see "Credit Summary" below).

Professional Requirements: The Professional Requirements which are not specified on the Plan of Study form are chosen in consultation with the student's advisor.

Restrictions: The following courses may not be counted for credit toward graduation: MATH 112Q and 118Q along with other mathematics courses numbered below 110Q; PHYS 101Q, 103Q; CSE 101C; STAT 100; and courses labeled "independent study" or "variable topics" (e.g.

courses numbered 298 and 299) taken in departments outside of the School of Engineering. No course taken on a Pass/Fail basis may be counted for credit toward graduation or used to meet any course requirement of the School of Engineering. Many general University restrictions are shown in the Academic Regulations and Procedures section of the University Catalog. Some examples include: Not more than 12 credits of biology at the 100-level may be counted toward graduation; Not more than 2 credits of ESLE 160 may be counted toward graduation; Not more than 6 credits from PHIL 101, 102, 103, 104, 105 may be counted toward graduation; and no credit for a course prerequisite to a second course in the same department may be counted for credit toward graduation after the student has passed the second course.

Exemption and Substitution: Students who desire to be excused from any of the requirements, or to substitute other courses for those prescribed, must do so by submitting a petition to the Director of Undergraduate Advising. Some examples of this type of departure from a published regulation are as follows: exemption from MATH 115Q for a student who had Calculus in high school and started in our MATH 116Q or substitution of PHYS 121Q, 122Q, 125Q for PHYS 151Q, 152Q. Note that a substitution of three courses for two (as in the Physics example) results in only the credits for the two being counted for graduation, i.e. you are making a substitution for the equivalent work. Note that substitutions for courses taken as departmental Professional Requirements usually do not require a petition for approval by the Dean, but may be indicated on the Plan of Study form directly. Students must not write down or leave unchanged anything on the Plan of Study that they have not actually taken or plan to take.

Transfer Courses: Transfer courses should be listed on the Plan of Study form just as any other course, with a superscript of "TC" to indicate which courses were transferred. The credit associated with each transfer course should be noted as explained in the next section (see "Credit Summary" below). Transfer courses may be counted at their University of Connecticut equivalent credit in the category totals if the transcript does not show the number of credits granted for the particular course.

For transfer work that does not have an exact University of Connecticut equivalent; e.g., 4.25 credits of BME 100 LEVEL, the credits should be listed as follows:

BME 100 LEVEL $(4.25)^{TC}$

In other words, the discipline followed by the level with an indication of how many credits is needed.

To aid students with transfer work, columns for sub-totaling "University of Connecticut Credits" and "Transfer Credits" are listed. These columns should be used to sum the credits across each row, separating those credits earned at University of Connecticut from those completed elsewhere.

The total transfer credit granted (not the sum of the University of Connecticut equivalents) less any equivalent restrictions (such as subtracting 3 credits if MATH 107Q is listed since this course does not count for credit in the School) should be listed on the line labeled "Transfer Credits". The total of all credits taken at the University of Connecticut should be listed on the line labeled "University of Connecticut Credits". The sum of the "Transfer Credits" and the "University of Connecticut Credits" should be listed on the "Total Credits" line. The total credits must equal or exceed 128.

Changes: Changes to a previously submitted Plan of Study form may be made in consultation with the advisor and will require submission of a "revised" Plan of Study form for approval, in the same manner as the "original" form was prepared and submitted. This may be done by marking the changes on the previously approved original Plan of Study form, available from the advisor or the Office of the Dean, and having the advisor initial and date each change. No modifications of a photocopy will be accepted. If a second revision of an "original" is necessary, of if extensive changes are to be made, the submission of a new "original" Plan of Study form is required. In the student's last semester, he/she must submit a "final" Plan of Study form which accurately lists all the courses that were taken to satisfy degree requirements.

APPENDIX: Engineering Accreditation and ABET Engineering Criteria 2000

The Accreditation Board for Engineering and Technology (ABET) is recognized in the United States as the sole agency responsible for accreditation of educational programs leading to degrees in engineering. The first statement of the Engineers Council for Professional Development (ECPD, now ABET) relating to accreditation of engineering educational programs was proposed by the Committee on Engineering Schools and approved by the Council in 1933. The original statement, with subsequent amendments, was the basis for accreditation until 2000. The statement presented here is required of programs beginning in 2005.

All accredited engineering programs must include engineering in the program title (An exception has been granted for programs accredited prior to 1984 under the title of Naval Architecture.) To be considered for accreditation, engineering programs must prepare graduates for the practice of engineering at a professional level.

It is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the following criteria.

I. GENERAL CRITERIA FOR BASIC LEVEL PROGRAMS

Criterion 1. Students

The quality and performance of the students and graduates are important considerations in the evaluation of an engineering program. The institution must evaluate student performance, advise students regarding curricular and career matters, and monitor student's progress to foster their success in achieving program outcomes, thereby enabling them as graduates to attain program objectives.
The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements.

Criterion 2. Program Educational Objectives

Although institutions may use different terminology, for purposes of Criterion 2, program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.

Each engineering program for which an institution seeks accreditation or reaccreditation must have in place:

(a) detailed published educational objectives that are consistent with the mission of the institution and these criteria
(b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated

(c) an educational program, including a curriculum that prepares students to attain program outcomes and that fosters accomplishments of graduates that are consistent with these objectives
(d) a process of ongoing evaluation of the extent to which these objectives are attained, the result of which shall be used to develop and improve the program outcomes so that graduates are better prepared to attain the objectives.

Criterion 3. Program Outcomes and Assessment

Although institutions may use different terminology, for purposes of Criterion 3, program outcomes are statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that student acquire in their matriculation through the program.

Each program must formulate program outcomes that foster attainment of the program objectives articulated in satisfaction of Criterion 2 of these criteria. There must be processes to produce these outcomes and an assessment process, with documented results, that demonstrates that these program outcomes are being measured and indicates the degree to which the outcomes are achieved. There must be evidence that the results of this assessment process are applied to the further development of the program.

Engineering programs must demonstrate that their students attain:

a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multi-disciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

In addition, an engineering program must demonstrate that its students attain any additional outcomes articulated by the program to foster achievement of its education objectives.

Criterion 4. Professional Component

The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution. The professional component must include:

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline

(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

Criterion 5. Faculty

The faculty is the heart of any educational program. The faculty must be of sufficient number; and must have the competencies to cover all of the curricular areas of the program. There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students.

The program faculty must have appropriate qualifications and must have and demonstrate sufficient authority to ensure the proper guidance of the program and to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and licensure as Professional Engineers.

Criterion 6. Facilities

Classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the program and institution.

Criterion 7. Institutional Support and Financial Resources

Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs.

Criterion 8. Program Criteria:

Each program must satisfy applicable Program Criteria. Program Criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. Requirements stipulated in the Program Criteria are limited to the areas of curricular topics and faculty qualifications. If a program, by virtue of its title, becomes subject to two or more sets of Program Criteria, then that program must satisfy each set of Program Criteria; however, overlapping requirements need to be satisfied only once.

For Biomedical Engineering, ABET curricular requirements are given as:

> "The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program.
>
> The program must demonstrate that graduates have: an understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology; the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems."