Biomedical Engineering (BMEN)

The Department of Biomedical Engineering is located in the Lindy Claiborne Boggs Center that includes more than 16,000 square feet of Biomedical Engineering office, laboratory, and classroom space. Major items of research equipment include:

Computers - Campus wide: IBM RS/6000 cluster.

Computers - Biomedical Engineering Server: SGI Origin 2000 DS 8 processor; Various workstations: Silicon Graphics, IBM RS/6000's, Sun, DEC Alpha, various PCs and Macintosh computers.

Image Analysis: PC and Macintosh with frame grabbers, scanners, etc.

Neurophysiology: Grass stimulators, amplifiers, and polygraph recorders.

Physiology Laboratory: A physiology laboratory is equipped to perform numerous physiology experiments and demonstrations.

Solid Mechanics: Digitally controlled MTS axial/torsional universal testing system, console-mounted and portable strain gage conditioners, ultrasonic testing apparatus.

Fluid Mechanics: Brookfield cone-plate viscometer, Cahn surface tension balance, flow visualization analysis system, Electronetics pulsating bubble surfactometer, computational fluid diagnosis software.

Experimental and Computational Tissue Mechanics: Universal Cartilage Testing Device, High Resolution Imaging System, ultrasound indentation probe, biosafety cabinet, centrifuge, microscope, incubator.

Biomaterials: EG&G PAR computerized electrochemical and polarographic measurement systems, metallographic specimen preparation equipment, Azur Environmental toxicity analyzer.

Electronics: Full suite of GPIB connected test equipment to support development of HC11 and Basic Stamp microcontrollers. LabVIEW is used for algorithm and control loop development and prototyping of implant, telemedicine, and monitoring applications.

Pulmonary Function: Spirometers, flow and pressure instrumentation, data acquisition, acoustic measurement systems.

Tissue Engineering: This facility is fully equipped for cell/tissue culture and a range of chemistry and microscopy techniques. Major equipment includes biosafety cabinets, centrifuges, microscopes, incubators, microplate washer and reader, FTIR.

New undergraduate laboratories are available for experiments associated with required courses in biomechanics (BMEN 212), medical sciences (BMEN 313/314), and bioelectronics (BMEN 373). These labs are also used in elective courses in biomechanics (BMEN 330), biomaterials (BMEN 323), and cell and tissue engineering (BMEN 340). A computer laboratory/classroom equipped with a smartboard and projector and 12 PC's, a printer and scanner are also available for undergraduates, particularly those taking BMEN 482 (required) and BMEN 361 (elective). These departmental research facilities are complemented by a machine shop and photographic dark room. In other branches of the university, advanced surface and chemical analytical facilities are accessible. Tulane's nine libraries house approximately 1.9 million volumes and has periodicals and on-line access to periodicals. These include the main university library (1.5 million volumes) and the Rudolph Matas Medical Library at the School of Medicine. Additional research facilities are available through the Department's ties with the LSU Medical School and LSU Dental School, both located in New Orleans.

The umbrella term **"Biomedical Engineering"** covers any application of engineering techniques and principles to problems and processes of biology or medicine. Such a broad class of study needs to be narrowed in order to achieve adequate depth, and the emphasis chosen by our faculty is—first and foremost—to provide students with the opportunity to acquire a rigorous engineering education. This basis then serves as a springboard to concentrated study of biomaterials, bioelectronics, bioelectricity, biomechanics and tissue engineering during the remaining undergraduate years, and will prepare you for graduate school, medical school, or a position in industry.

The Department was founded in 1977, so we are a relatively mature department in a new field—a field in which the potential for making meaningful contributions is unlimited. Our backgrounds are diverse, covering the areas of biomechanics, biomaterials, bioelectronics, bioelectricity and tissue engineering. Our undergraduate teaching program is extensive, with approximately 40 seniors graduated each year. All of us on the faculty are actively engaged in research sponsored by federal, state and/or private organizations, and we believe that this enhances our teaching abilities by keeping each of us in the forefront of knowledge in our specialties.

DEPARTMENTAL MISSION

The faculty and staff of the Department of Biomedical Engineering strive to provide the highest quality education and research opportunities for our students.

We expect and value excellence in teaching undergraduate and graduate courses, conducting research, and training students to participate in research activities and professional practice.

We accomplish our Departmental Mission and we evince the core values of Tulane University as follows:

- Through the scholarship of discovery, we develop, integrate, and apply new ideas through innovative, interdisciplinary research approaches.
- Through the scholarship of learning, we develop the knowledge and skills necessary to participate in biomedical engineering analysis, design, and research.
- Through the scholarship of service, we share knowledge to advance the opportunities and the significance of biomedical engineering in efforts that ultimately improve health and quality of life.

DEPARTMENTAL VISION

The Department of Biomedical Engineering is committed to being a global leader in biomedical engineering scholarship. Our faculty, staff, and students are all important parts of the team that will complete our missions of: excellence in undergraduate and graduate education; meaningful and innovative research; and service dedicated to advancing the field of Biomedical Engineering.

PROGRAM EDUCATIONAL OBJECTIVES

To fulfill our Departmental Mission and Vision, we endeavor to achieve a set of objectives which can be classified in three broad, interrelated categories: Program Instruction, Faculty, and Facilities and Support. Our educational objectives are constructed to yield an environment where students take active control of, and exhibit pride in, their education; view the department, the School of Engineering, and Tulane University as learning-oriented communities and themselves as integral parts of those communities; develop the broad base of critical thinking abilities, technical knowledge, and engineering skills crucial to professional practice in Biomedical Engineering and related careers.

UNDERGRADUATE INSTRUCTIONAL OBJECTIVES

We give our students strong foundations in engineering, mathematics, and the life and basic sciences, in a coherent and coordinated curriculum. We provide our students with unique opportunities to conduct focused research or design projects in areas of individual interest, and we prepare our students for a successful transition to advanced study and professional careers. Specifically, students who obtain a bachelor’s degree from our department will be able to:

1. Understand and apply principles and tools of mathematics, science, and engineering to formulate and analyze problems, specializing in issues found at the interface between biological and technological systems.
2. Compose and test hypotheses, and interpret resulting data.
3. Design systems, devices and processes to meet designated specifications or open-ended objectives; evaluate and justify the resulting designs within contemporary cultural and broad societal contexts.
4. Work effectively in multidisciplinary teams.
5. Exemplify professionally and ethically responsible conduct.
6. Seek and value opportunities for extracurricular and post-graduate education and development.
7. Communicate the short- and long-term challenges and opportunities inherent in the field of Biomedical Engineering to both technical colleagues and the general public.

GRADUATE PROGRAM INSTRUCTIONAL OBJECTIVES

We enhance the academic preparation of our graduate students in engineering, mathematics, and the life and basic sciences. Our graduate students are our junior colleagues, and we furnish them with the advanced and current coursework, professional guidance, and equipment/facilities which are critical to their participation in biomedical engineering research and scholarship. We coach our students as they conduct independent research and pursue careers related to one of the major themes of biomedical engineering (e.g., bioelectronics, biomaterials, biomechanics, cell/tissue engineering, or instrumentation).

CURRICULUM

The undergraduate program in Biomedical Engineering is built upon a rigorous engineering science foundation that is, in turn, based upon a broad curriculum of natural sciences, mathematics, electives in humanities and social sciences, and design. Although students are encouraged to concentrate their professional electives in a sub-field of interest in biomedical engineering (*e.g.*, biomechanics, bioelectronics, bioelectricity, biomaterials, or tissue engineering) or medical sciences (for pre-med students), there are no formal “tracks” within the sequence. The undergraduate curriculum is primarily designed to prepare our undergraduates for advanced study. More than two-thirds of our BSE graduates continue on to graduate or professional training after graduation from Tulane. We have a philosophy of ‘rigorous breadth’ in biomedical engineering which can best be characterized by the undergraduate curriculum described below.

Tulane University BMEN Undergraduate Curriculum

Year 1

Semester One

MATH 121	Calculus I	(4)
CHEM107/117	General Chemistry I and Lab	(4)
ENGL 101	Writing	(4)
PHYS 131	General Physics I and Lab	(4)
ENGR 100	Engineering Seminar	(1)

Semester Two

MATH 122	Calculus II	(4)
CHEM 108/118	General Chemistry II and Lab	(4)
CPSC 116	Intro to Computing via C	(4)
PHYS 132	General Physics II and Lab	(4)
BMEN 102	Elements of BME Design	(2)

Year 2

Semester One

MATH 221	Calculus III	(4)
CELL 101/211	General Biology I and Lab	(4)
HUSL	Human/Social Sciences Elective	(3)
ENGR 241	Statics	(3)
BMEN 201	Experts. & Experimental Design	(2)
BMEN 203	Drawing & Visualization	(1)

Semester Two

MATH 224	Applied Math (Diff Eqns.)	(4)
ENGR 201	Electric Circuits I	(3)
BMEN 260	Intro Organic & Bio-Chemistries	(3)
ENGR 243	Mechanics of Materials	(3)
BMEN 212	BMEN Lab	(2)

Year 3

Semester One

BMEN 303/313	Med. Sci. for Engineers I and Lab	(4)
BMEN 373	Biomedical Electronics and Lab	(4)
HUSL	Human/Social Sciences Elective	(3)
BMEN 3xx**/482	“Bridge” class or Model. Bio Sys.	(3)
ENGR 344	Fluid Mechanics	(3)
BMEN 371	BMEN Seminar	(0)

Semester Two

BMEN 304/314	Med. Sci. for Engineers II and Lab	(4)
ENGR 312	Materials Sci and Eng	(3)
HUSL	Human/Social Sciences Elective	(3)
BMEN 3xx**	“Bridge” class	(3)
BMEN 490	Research & Professional Practice I	(2)
BMEN 372	BMEN Seminar	(0)

Year 4

Semester One

ELECTIVE	Professional Elective	(3)
HUSL	Human/Social Sciences Elective	(3)
HUSL	Human/Social Sciences Elective	(3)
BMEN 3xx**/482	3xx, 6xx or Modeling Bio Sys.	(3)
BMEN 491	Research & Professional Practice II	(2)
BMEN 403	Team Design I	(2)
BMEN 671	BMEN Seminar	(0)

Semester Two

ELECTIVE	Professional Elective	(3)
ELECTIVE	Professional Elective	(3)
HUSL	Humanities/Social Sciences Elective	(3)
BMEN 3xx*/6xx***	“Bridge” class or 6xx	(3)
BMEN 404	Team Design II	(2)
BMEN 672	BMEN Seminar	(0)

"Bridge" classes

*BMEN 323 Biomaterials (Fall)

*BMEN 361 Bioelectricity (Fall)

**BMEN 330 Biomechanics (Spring)

**BMEN 340 Cell and Tissue Engineering (Spring)

***BMEN 6XX courses are graduate courses, one of which is required in the domain of focus, generally choosing from the following:

BMEN 611 Cardiac Electrophysiology

BMEN 614 Biomedical Signal Analysis

BMEN 626 Biomaterials Research Problems and Methodology

BMEN 627 Biomaterials and Biocompatibility

BMEN 628 Surgical Applications of Biomaterials

BMEN 633 Bio Fluid Mechanics

BMEN 634 Soft Tissue Mechanics

BMEN 635 Advanced Soft Tissue Biomechanics

BMEN 636 Introduction to the Finite Element Method

BMEN 639 Advanced Finite Element Methods

BMEN 643 Advanced Topics in Cell/Tissue Engineering (Cell and Tissue Mechanics)

BMEN 645 Advanced Topics in Cell/Tissue Engineering (Brave New World)

BMEN 661 Introduction to Computational Biomechanics

BMEN 664 Bone Mechanics

BMEN 666 Cardiovascular Biomechanics

BMEN 667 Pulmonary Mechanics

BMEN 674 Data Acquisition and Control

BMEN 676 Advanced Topics in Excitable Media

Professional Electives

The professional electives include at least two of the BMEN 300-level elective 'bridge' courses and at least one of the follow-up BMEN 600-level courses. The other professional elective courses may be any courses that meet the student's professional goals. Up to two ROTC courses may be used to meet this requirement.

Premedical students may use the professional electives in the junior year to take organic chemistry. Many premedical students prefer to take organic chemistry during the summer, however. Some medical schools require a second English course, and this can be one of the humanities electives. Most medical schools also require an additional semester of Biology with lab, and this is also considered as a professional elective.

Humanities and Social Science Electives

In the interest of making engineers more aware of their social responsibilities and better able to consider related factors in the decision making process, coursework in humanities and social sciences is an integral part of our program. In light of this, the curriculum requires a minimum of six courses of acceptable humanities and social science electives in addition to

English 101. These courses must be chosen to provide both breadth and depth and should not be a selection of unrelated introductory courses. Courses which focus primarily on the routine exercise of personal craft are not acceptable. A list of acceptable electives is available in the Engineering Dean's Office.

While the School of Engineering does not require a foreign language, it is highly recommended that students with a talent and background in languages consider using a language for some of the coursework to meet the humanities and social sciences requirement. Engineering has become increasingly global, and a background in a foreign language and culture may be quite important to one's career.

Students must satisfy the following requirements:

A. At least one course must be selected from the humanities and at least one from the social sciences.

B. At least one course must be selected from a list of courses on World Culture.

C. To meet the breadth requirement, courses must be selected from at least three different departments.

D. To meet the depth requirement, at least two courses must be selected in each of two departments.

Research and Design Experiences

Hallmarks of our curriculum are the research and design experiences that are coordinated through the two semester sequences in Professional Practice and Design (490, 491) and Team Design (403, 404). Every student participates in an individual research project as well as a team design project.

The team design projects, which recently have been supported by the National Science Foundation and the Joe W. and Dorothy Dorsett Brown Foundation, are tailored to the needs of individuals with disabilities who are referred to the department by several community agencies. The team designs are evaluated for safety and then presented and judged in a public design competition. The class of 2002 completed nine team projects (generally four students per team) and a list and brief description is included in the *Appendix*. The team design experience of working for an extended period with a handicapped client—while having the opportunity to apply engineering foundations and real world design and construction skills to assist the client—has been extremely rewarding for our students.

In addition to the team design project, each student participates in an individual year-long research project generally with a biomedical engineering faculty member or with faculty in departments of the Tulane or LSU medical schools. The list of research projects completed by the class of 2002 covers an impressive range of activities. The students thus have substantial research experience—*while still undergraduates*—that includes writing a comprehensive thesis describing the research performed and an oral presentation of the work to the faculty and fellow students in departmental seminar, BMEN 672.

MINORS FOR BIOMEDICAL ENGINEERING STUDENTS

All Engineering students have the option of earning a variety of minors. Specific examples include Mathematics and Business and are described in the Undergraduate Catalog. In addition, for Biomedical Engineering majors, a minor in Mechanical Engineering, Electrical Engineering, or Exercise and Sports Science are available.

NOTE: The requirements described below are determined by the respective departments, and are subject to change and/or revision – so check with the listed department or a faculty advisor before beginning one of these sequences.

BMEN/ME: A Biomedical Engineering major wishing to complete a minor in Mechanical Engineering should check with Mechanical Engineering for current requirements.

BMEN/EE: A Biomedical Engineering major wishing to complete a minor in Electrical Engineering should check with Electrical Engineering for current requirements.

BMEN/EXSS: The Exercise and Sports Science Department's curriculum specifies that the following courses must be taken by a student wishing to receive a minor from that department: EXSS 201, 202, and 311; plus 3 additional courses chosen from EXSS 203, 310, 316, 375, 401, 402, and 419. A BMEN major can satisfy these requirements in the following ways:

EXSS 201 BMEN 303 may be substituted for this course

EXSS 202 counts as a BME Professional Elective

EXSS 311 counts as a BME Humanities / Social Sciences Elective

EXSS 203 BMEN 304/314 may be substituted for this course

EXSS 375 counts as a BMEN Professional Elective

EXSS 402 counts as a BMEN Professional Elective

EXSS 419 counts as a BMEN Humanities / Social Sciences Elective

Minor In Biomedical Engineering
Students in other engineering departments may earn a Minor in Biomedical Engineering through completion of the following courses:

CELL 101 Cell Biology

BMEN 260 Introduction to Organic and Biochemistries

BMEN 303/313 Medical Science for Engineers I, with lab

BMEN 304/314 Medical Science for Engineers II, with lab

And 1 course selected from:

BMEN 330 Biomechanics

BMEN 340 Cell and Tissue Engineering

BMEN 361 Bioelectricity

BMEN 323 Biomaterials (Note: requires ENGR 312 as a prerequisite)

FACULTY AND COURSE DESCRIPTIONS

Office: Suite 500, Lindy Claiborne Boggs Center

Phone: (504) 865-5897

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email: info@bmen.tulane.edu

Professors

Kirk J. Bundy, Ph.D., Stanford University, 1975. Biomaterials, corrosion, bioadhesion, environmental science, biosensors.

Richard T. Hart, Alden J. 'Doc' Laborde Professor and Department Chair; Ph.D., Case Western Reserve University, 1983. Mechanics of bone, finite element methods, functional adaptation, ocular biomechanics.

Donald P. Gaver, Assistant Chair, Director of Graduate Studies; Ph.D., Northwestern University, 1988. Biofluid mechanics, pulmonary mechanics, bioremediation, biocomputing.

Paul L. Nunez, Ph.D., University of California at San Diego, 1969. Electroencephalography, signal processing, neocortical dynamics.

Natalia A. Trayanova, Ph.D., Sofia University, Bulgaria, 1986. Theoretical and computational electrophysiology, normal and abnormal cardiac rhythms, cardiac pacing and defibrillation, scientific visualization.

Cedric F. Walker P.E., Director, Individually Designed Major Program; Ph.D., Duke University, 1978. Telemedicine, neural stimulation, implantable monitoring devices.

Associate Professors

Ronald C. Anderson, Ph.D., Tulane University, 1987. Biomechanics, orthopædic materials.

David A. Rice P.E., Director of Undergraduate Studies; Ph.D., Purdue University, 1974. Physiologic modeling, cardiopulmonary mechanics, bioacoustics, instrumentation and signal processing.

Jun-Kyo Francis Suh, Ph.D., Rensselaer Polytechnic Institute, 1989. Mechanics of collagen based connective tissues, cartilage tissue engineering, repair of articular cartilage defects, brain injury, computational biomechanics.

Assistant Professors

Kay C Dee, Ph.D., Rensselaer Polytechnic Institute, 1996. Cell/Tissue engineering, biomaterials, cell adhesion, engineering education.

Glen A. Livesay, Ph.D., University of Pittsburgh, 1996. Experimental and theoretical mechanics, soft tissue and joint mechanics, engineering education.

Eric A. Nauman, Ph.D., University of California at Berkeley, 2000. Tissue engineering of bone and nerve tissue, degenerative diseases, mechanical loading of cells, mechanics of hierarchical materials, dynamics of biological systems.

Professor Emeritus

William C. Van Buskirk P.E., Professor and Chair Emeritus of Biomedical Engineering, Dean Emeritus of Engineering; Ph.D., Stanford University, 1970 (currently Provost at New Jersey Institute of Technology).

COURSES IN BIOMEDICAL ENGINEERING

A course with a three-digit number, such as 101, lasts for one semester. Odd numbered courses are usually given in the first semester; even numbered courses are usually offered in the second semester. A course with a double number, such as 101-102, lasts for both semesters.

Courses with numbers from 100 to 199 are ordinarily open to freshmen; 200 to 299 are ordinarily open to sophomores; 300 to 399 are ordinarily open to juniors; 400 to 499 are ordinarily open to seniors; 600 to 699 are open to advanced undergraduate and graduate students; and 700 to 799, to graduate students only.

Regularly Scheduled Courses

BMEN 102 Elements of BME Design (2)
Introduction to research and design for freshman expressing an interest in biomedical engineering. Topics include a survey of departmental research projects, discussion of form and function in living systems, and the fundamentals of the engineering design process. Student teams will have the opportunity to interact with faculty advisors to explore and present aspects of ongoing departmental research projects.

BMEN 201 Experiments & Experimental Design (3)
Prerequisite: BMEN 102. This course investigates measurement, error analysis and the treatment of uncertainties in biomedical engineering. Students will be provided an introduction to statistics, including probability and distributions, confidence intervals, sampling and hypothesis tests on the mean. Sources of potential bias (and how to avoid them) and various experimental designs commonly utilized in biomedical engineering will also be explored. Useful computational tools will be introduced and utilized throughout the course.

BMEN 212 BMEN Lab (2)
Prerequisite: BMEN 201; Corequisite: ENGR 243. This course builds upon ideas from BMEN 201 (Experiments and Experimental Design) and complements ENGR 243 (Mechanics of Materials) with hands-on mechanics laboratory experience. Students will

perform tests to determine structural responses to mechanical loads and subsequently analyze the data. These tests will include traditional mechanics applications (e.g. applying/wiring strain gauges to metal test specimens) as well as tests more commonly utilized in biomechanical engineering. Various analysis and software simulation tools will also be introduced.

BMEN 260 Introduction to Organic and Bio-Chemistries (3)
Prerequisite: CHEM 108 and CHEM 118, or approval of instructor. This course introduces the main principles of Organic Chemistry and Biochemistry preparing the student for BMEN 303/304. Topics include nomenclature of organic compounds and biomolecules, major reaction of organic chemistry, relationship between chemical structures and biological functions, and the reaction pathways of major metabolic processes. Students will be introduced to the three-dimensional structure of organic compounds and biomolecules using molecular models and software tools.

BMEN 303/703 Medical Science for Engineers I (3)
Prerequisites: MATH 224; BMEN 260; CELL 101, Corequisite: BMEN 313. The first of two sequenced courses intended to introduce quantitative physiology. Introductions to biochemistry and human anatomy are presented and the course places special emphasis upon the chemical basis of life; cells and cellular metabolism; histology and tissues; the endocrine, skeletal and nervous systems.

BMEN 304/704 Medical Science for Engineers II (3)
Prerequisite: BMEN 303; Corequisite: BMEN 314. The second in a sequence intended to introduce quantitative human physiology. Special emphasis is given to the respiratory, digestive, cardiovascular, lymphatic and reproductive systems; nutrition and metabolism; water, electrolyte and acid-base balance, and human growth and development.

BMEN 313/713 Medical Science for Engineers Lab I (1)
Corequisite: BMEN 303. This course involves students in learning the principles and applications of anatomy and physiology. Dissection and exploration of preserved animals and cadavers are integral components of the lab. Computer software is used to explore the three-dimensional aspects of human anatomy. Physiological instruments will be used to demonstrate the interaction of physiological systems through electrocardiography, Spirometry, pO2 and pCO2, and for body composition analysis. Subject matter will include levels of organization, metabolism, histology, and the integumentary skeletal, muscular, neurological and endocrine systems.

BMEN 314/714 Medical Science for Engineers Lab II (1)
Corequisite: BMEN 304. Continuation of BMEN 313. Subject matter will include blood, nutrition, and metabolism; and the cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems.

BMEN 323 Biomaterials (3)
Prerequisite: ENGR 312. The objective of this course is to deepen the student's knowledge of phenomena that influence the success of surgical implants used
in vivo. Building upon the introductory material covered in ENGR 312, basic concepts of materials science and engineering relevant to this topic are discussed. In addition to engineering performance issues, fundamental factors affecting the bicompatibility of implant devices will also be covered. Laboratory experiments will be utilized, in a supplemental fashion, to illustrate selected aspects of this material and to provide an introduction to procedures used to evaluate biomaterials. This course will serve as a bridge for students who wish to take more advanced graduate level biomaterials courses in the future.

BMEN 330/730 Biomechanics (3)
Prerequisite: ENGR 243
This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: kinematics and energy/power during human activity; dynamics of human movement; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials; and the relationship between structure and function in tissues and organs.

BMEN 340/740 Cell and Tissue Engineering (3)
Prerequisite: BMEN 260. This course addresses the complex interactions between living tissues and implant biomaterials, stressing the importance of cellular- and molecular-level phenomena in macroscopic, tissue-level events. After taking this course, students will be able to explain the roles of cells/tissues and biomaterials in coagulation and fibrinolysis, inflammation, wound healing, hypersensitivity and foreign-body responses, and carcinogenesis. Current cell and tissue engineering research topics will be incorporated into class discussions and laboratory projects.

BMEN 361/761 Bioelectricity (3)
Prerequisite: ELEN 201 or ENGR 201. The objective of this course is to introduce the student to bioelectricity of excitable cells from a quantitative perspective. Topics include membrane transport phenomena, the ionic basis of action potentials, the Hodgkin - Huxley model, propagation of action potentials down excitable fibers, the response of cells to external stimuli, and the current flow in the medium surrounding the electrically-active cell. The course also incorporates virtual bioelectricity labs designed to familiarize the student with the concepts presented in lecture.

BMEN 373/773 Biomedical Electronics with Lab (4)
Prerequisite: ELEN 201 or ENGR 201. Rectifiers, filters, regulators and power supplies. Analog amplifiers and active filters of interest for medical devices. Combinational and sequential digital logic design techniques and circuits. Brief overview of modulation, encoding, and interfacing. Electrical safety. Extensive weekly lab projects.

BMEN 403-404 Team Design Project I and II (2,2)
Prerequisite: Senior standing. Techniques and experience in the solution of constrained and open-ended design problems. Lecture topics include all aspects of the design process, including goal setting, idea generation, prototyping, fabrication, and product and evaluation. Also included are technical presentation,k project planning and management. Included as needed are other topics such as standards, fastening and joining, motors and control, esthetics and finish. Each team will design and construct a device or system to assis an individual with a disability. These designs are presented in a public show during the second semester.

BMEN 482/682 Mathematical Modeling and Analysis of Biological Systems (4)
Prerequisite: MATH 224. The objective of this course is to teach basic mathematical modeling constructs and analysis techniques that are used for studying biological processes. Topics to be covered include ordinary differential equations, compartment systems, basics of dynamic systems, stability, statistical inference and model construction. These will be applied to study models of chemical kinetics, physiological control, AIDS transmission, population dynamics, and growth. Students will use Mathematica to develop and analyze models.

BMEN 490-491 Biomedical Research and Professional Practice I and II (2,2)
This course introduces the tools, techniques, and rules necessary to function professionally as a researcher or engineer. Topics include economic analysis, ethics, professional communication including writing and oral presentation, research techniques including literature searching, citation, and the structure of a scientific paper. An integral part of the course is a year-long research or design project under the direction of a faculty member or other scientist or professional. This culminates in a Senior Thesis and a presentation in Departmental Seminar.

BMEN 611 Cardiac Electrophysiology (3)
Prerequisite: BMEN 361. An engineering perspective on the electrical behavior of the heart. Topics include the normal electrical excitation of the heart, membrane ionic channels, contraction, the basics of electrocardiography, arrhythmias and mechanisms of arrhythmogenesis, sudden cardiac death, and the electrical therapies for disturbances in cardiac rhythm. Virtual labs are also included to aid the learning process.

BMEN 627 Biomaterials and Biocompatibility (3)
Prerequisite: BMEN 323 or equivalent. Building upon the fundamental material presented in BMEN 323, this course discusses structure-property relationships for the metallic, polymeric, ceramic, and composite materials used in surgical implants. Factors involved in the design of implants and processes used in their manufacture are also presented. Various aspects of biocompatibility are discussed in terms of effects (such as corrosion and wear) that the host environment has on implant materials, effects that species released by degradation processes have on the host tissues, and test methods for the study of these effects.

BMEN 633 Fluid Mechanics for Biomedical Engineers (3)
Prerequisites: ENGR 243, ENGR 344. This course will cover general intermediate/advanced fluid mechanics, and will provide a foundation from which to base one's studies of biofluid mechanics. Issues pertinent to the study of biofluid mechanics will be emphasized. Topics to be studied include kinematic principles, the Navier-Stokes equations, boundary conditions for viscous flows, basic solutions to steady and unsteady Navier-Stokes equations, turbulence, analysis of the vorticity equation, and interfacial phenomena. Whenever possible, problems of a biological nature will be used as examples.

BMEN 634 Soft Tissue Mechanics (3)
Prerequisite: ENGR 243, BMEN 330. This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. An important objective of this class is to enable the student to develop a sense for the physical and mathematical relationships between the many types of models (and the associated experiments) currently being utilized in soft tissue mechanics.

BMEN 635 Advanced Soft Tissue Biomechanics (3)
Prerequisite: BMEN 634, BMEN 636. The class is designed to provide students with advanced modeling topics in musculoskeletal soft tissue biomechanics. The course material will consist of an introduction to the anatomical structure of various musculoskeletal soft tissues such as ligament, tendon, and cartilage, followed by fundamentals and general principles in mechanics necessary to understand mathematical modeling of these tissues. The main focus will be placed on various viscoelastic modeling of soft tissues, such as linear, nonlinear and quasi-linear viscoelastic modelings. A viscoelastic model based on mixture theory, such as biphasic poroelastic model and biphasic poroviscoelastic model will also be introduced. The models will be studied mostly using typical simple loading conditions. They include creep, stress relaxation, and cyclic loading of such models.

BMEN 636 Introduction to the Finite Element Method (3)
Prerequisite: ENGR 330 or equivalent. Matrix structural analysis techniques as applied to frames, problems in plane strain, plane stress, and axisymmetric and 3-D structures. Development of the isoparametric family of finite elements. Use of user written and packaged software.

BMEN 643 Adv. Topics in Cell/Tissue Engineering: Cell and Tissue Mechanics (3)
Prerequisite: BMEN 330 or 340. Inspired by the video and flipbook “Powers of Ten” by Charles and Ray Eames, this course explores biomechanical models and experiments from the length scale of a cell membrane to that of a human being, stepping from topic to topic by incremental length multiplications of powers of ten. Students learn to recognize and critically evaluate scale-dependent assumptions and results; develop their intuitive understanding of scale; and expand their knowledge of biomechanics.

BMEN 645 Adv. Topics in Cell/Tissue Engineering: Brave New World (3)
Prerequisite: BMEN 640/340. This course focuses on scientific and ethical issues surrounding cell and tissue engineering themes in selected works of science fiction. Topics covered in the past have included embryo research, cloning, organbanking/organ replacement, anti-aging technologies, cosmetic tissue engineering, human/AI links, and nanotechnology. Students trace the development of ideas/technology, discover the current state-of-the-art, and project future directions of the field of cell and tissue engineering.

BMEN 661 Introduction to Computational Biomechanics (3)
This course covers fundamentals of computational methods with the emphasis in biomechanics applications. The computational methods include finite element methods and finite difference methods at the introductory level. The course will use MATLAB as the official computational tool to implement these methods. The underlying theories of these numerical methods will be taught, and example problems will be discussed during the lecture. Example problems will include those from implant design, bone biomechanics, soft tissue biomechanics, etc. in static and dynamic conditions. The course will also discuss some special issues such as the stability/convergence criteria and the error estimation. The student will work on a term project to exercise these issues on a biomechanics problem of his/her choice.

BMEN 665 Structure-Function Relationships in Biological Tissues (3)
Prerequisites: BMEN 634 or ENGR/BMEN 631. This course provides a review of the mechanics of finitely deformable structures and thermomechanics with applications to the study of biological tissues. The focus of the course will be on the development of mathematical models describing fluid-solid interactions in biological tissues, nutrient transport, damage repair, and discontinuities. In particular, we will cover mixture theory, poroelasticity, microstructural models of cortical and cancellous bone, tendon, ligament, and other tissues, transient and steady-state nutrient transport, and continuum damage theories.

BMEN 667 Pulmonary Mechanics (3)
Prerequisites: MATH 224, BMEN 633 or equivalent. This is a survey course in which mechanical models of the pulmonary system are discussed. Topics to be addressed include mucous transport, airflow/diffusion in the pulmonary airways, ventilation/perfusion relationships, flow through collapsible airways and interfacial phenomena.

BMEN 671-672 Departmental Seminar (0)
Each week, a one-hour seminar on research within or outside the department is presented. During the Spring semester, all seniors are required to give a presentation on their project or internship. Attendance of all graduate students is required in the Fall semester.

BMEN 674 Data Acquisition and Control (3)
Prerequisite: ELEN 303 or BMEN 373. Acquisition, digital processing, and output of signals of biomedical interest. Closed loop control applications for medical devices. Programming in the National Instruments LabVIEW environment. In-lab and final projects.

BMEN 676 Advanced Topics in Excitable Media (3)
Prerequisite: BMEN 361. This course addresses the generic behavior of excitable media such as nerve and muscle tissues, and oscillating chemical reactions. The course focuses on the generic mathematical models pertinent to excitable media and the non-linear-dynamics tools for analyzing them. Topics include: the membrane as a first order system, the FitzHugh-Nagumo model, phase-plane analysis, limit cycles and oscillatory responses of the membrane.

BMEN 685/686 Seminar in Biofluid Mechanics (0)
A weekly seminar in biofluid mechanics, concentrating especially on fluid mechanics relevant to the pulmonary and circulatory systems. The seminar is journal club format, with weekly presentation and discussion of papers taken from the recent literature.

BMEN 721-722 Directed Readings in Biomedical Engineering (1-6)
Taught on a tutorial basis, this course allows a student to make an in-depth study in an area of expertise of members of the department. Some recent and current topics include non-Newtonian fluid mechanics; the mechanics of the inner ear; the mechanics of bone; the mechanics of soft tissue; ceramics engineering; physical metallurgy; laser applications in medicine; and modeling of neural networks.

BMEN 751 Teaching Engineering (2)
Required for entering Teaching Assistants and all incoming graduate students; suggested for students interested in pursuing academic careers. A weekly seminar on techniques and methods for effective teaching and learning in engineering. Topics covered include: syllabus assembly and evaluation, teaching methods and classroom management, grading and assignment/exam design, lecturing skills, cognitive development, classroom assessment techniques, self-assessment and evaluation.

Less Frequently Scheduled Courses

BMEN 602 Biosystems (3)
Prerequisite: MATH 224. Fundamentals of biological control systems modeling, open and closed loop systems, transfer functions, stability, time and frequency response, analysis and synthesis of systems. Applications include modeling of physiological systems, instrumentation, and artificial organs design.

BMEN 606 Biomedical Acoustics (3)
Prerequisite: BMEN 304, MATH 221. Introduction to sounds in the physiological and medical arena. Topics include: physics of sound propagation, sources and mechanisms of cardiac and respiratory sound production, sound transmission, auscultation and stethoscope evaluation, psychoacoustics and auditory perception, speech production and structure of the speech signal, medical ultrasound applications and safety.

BMEN 612 Electric Fields of the Brain (3)
Introduction to neocortical physiology and anatomy. Overview of Electroencephalography (EEG). Neural current sources. Solutions of the membrane diffusion equation. Solutions of Poisson's equation in a head-like medium. Integration of time series analysis with volume conduction theory. Methods of analysis of EEG and evoked potential data. The brain's magnetic field. Linear and nonlinear models of neural interaction and their relationships to EEG and cognitive processing.

BMEN 614 Biomedical Signal Analysis (3)
Prerequisites: CPSC 101, MATH 221, and MATH 224. Stationary random process theory. Power spectra, cross spectral density and coherence estimates. Cross correlation and correlation function coefficients. Basic statistical concepts. Statistical significance of estimates. Nonstationary and transient data. Application to multichannel electroencephalographic data. Use of IMSL software.

BMEN 615 Interactions of External Electromagnetic Fields with Humans (3)
Prerequisite: MATH 224. This course considers the environmental and medical effects of a broad spectrum of electromagnetic fields ranging from power line fields to x-rays. Quasi-static fields. Maxwell's equations. Near and far fields. Refection and transmission of electromagnetic waves at boundaries. Fields due to transmission lines and antennas. Diathermy, inductive osteogenesis, and imaging.

BMEN 616 Neural Augmentation (3)
Prerequisite: BMEN 373. Implantable and external electrical stimulation devices and technology for the control of pain, functional electrical stimulation, and other neural prostheses are discussed. Additionally, the anatomy of the central nervous system is taught through the use of a programmed learning sequence.

BMEN 618 Electrodiagnosis (3)
Prerequisite: BMEN 373. Application of medical instrumentation in clinical diagnosis including EKG, EMG, multimodality evoked potentials, stress tests, ultrasound, and computed tomography. The lectures cover the system design of the instruments and review the conditions they are designed to detect. The lab consists of an applications demonstration in one of the local medical facilities.

BMEN 626 Biomaterials Research Problems and Methodology (3)
Prerequisite: BMEN 323. This course emphasizes a detailed consideration of selected topics which are currently the focus of biomaterials research, as well as consideration of experimental and theoretical methodology used to approach these and other biomaterials problems. The specific topics will change from year to year as the field of biomaterials develops.

BMEN 628 Surgical Applications of Biomaterials (3)
Prerequisite: BMEN 627 or equivalent. This course emphasizes specific uses of biomaterials in various branches of surgery, the specific materials that are used, and problems that may be a consequence of such use. Topics discussed include orthopædic, cardiovascular, dental, and other applications.

BMEN 631 Continuum Mechanics (3)
Prerequisite: ENGR 243, ENGR 344. The course begins with a presentation of the kinematics of continuous media. It covers the conservation principles of mass, momentum and energy, the thermodynamics of continuous media, the formulation of constitutive equations, and the elements of linear and nonlinear elastic fluid theories. The applications discussed in detail are the modeling of the mechanical behavior of bone and skin, and the mechanical and thermal behavior of muscle tissue.

BMEN 639 Advanced Finite Element Methods (3)
Prerequisite: BMEN 636. This is the second course in finite element analysis that will expand upon the introductory course, BMEN 636. Included in the topics to be addressed are the theory and application of weighted residual methods, dynamic mode shape and time series analyses, geometric and material non-linearities, contact problems, and thermal and electric field problems. The BMEN Origin 2000 will be used for running ABAQUS and/or ABAQUS/EXPLICIT to solve all application problems.

BMEN 640/340 Biomaterial-Tissue Interactions (3)
Prerequisite: Junior, Senior or Graduate student standing. Current Topics and experimental issues relevant to the cell-biomaterial interface and tissue engineering are explored.

BMEN 646 Nonlinear Phenomena and Chaos (3)
Prerequisite: MATH 224. Review of linear systems: Classical nonlinear theory. Nonlinear mechanical, electrical, and biological systems. Dufng and Vander Pol systems. History of chaos. How to identify chaotic vibrations. Nonlinearity and spatial scale. Taught at introductory level.

BMEN 647 Nonlinear Dynamics (3)
Prerequisite: BMEN 646. Dynamics of physical and biological systems. Theoretical ecology and neural networks. Numerical methods for nonlinear equations. Systems with spatial extent. Stable spatial structure with temporal chaos. Statistical methods. Emphasis is placed on a short research project selected by the student.

BMEN 664 Bone Mechanics (3)
Prerequisite: BMEN 636 and approval of instructor. The objective of the course is to provide students with an opportunity to pursue an in depth examination into current methods and results in bone mechanics research. Of particular interest is the study of the anatomy and physiology of bone