DEPARTMENT OF BIOMEDICAL ENGINEERING

Programs

Undergraduate

Major

- Biomedical Engineering Major (https://catalog.tulane.edu/science-engineering/biomedical-engineering/biomedical-engineering-major/)

Minors

- Biomedical Engineering Minor (https://catalog.tulane.edu/science-engineering/biomedical-engineering/biomedical-engineering-minor/)
- Biomedical Engineering Minor for Non-Engineering Majors (https://catalog.tulane.edu/science-engineering/biomedical-engineering/biomedical-engineering-minor-non-engineering-majors/)

Graduate

- Biomedical Engineering, MS (https://catalog.tulane.edu/science-engineering/biomedical-engineering/biomedical-engineering-ms/)
- Biomedical Engineering, PhD (https://catalog.tulane.edu/science-engineering/biomedical-engineering/biomedical-engineering-phd/)

Courses

Biomedical Engineering (BMEN)

BMEN 1005 Introduction to Musculoskeletal Anatomy and Biomechanics (3)
This course will introduce high school students to basic biomedical concepts and measurements, as well as lay a foundation for understanding and using technical terminology employed by preclinical students and medical professionals. We will focus on the anatomy and physiology of the musculoskeletal systems and their interplay with other systems in the human body. In addition to lectures, students will gain hands-on measurement experience utilizing modern techniques while also gaining hands-on biomedical design experience through labs and activities. This course is limited to high school students.

BMEN 1940 Transfer Coursework (0-20)
Transfer Coursework at the 1000 level. Departmental approval may be required.

Maximum Hours: 99

BMEN 2020 Computing Concepts & Applic (4)
This course introduces students to the foundations of algorithm development and programming, basics of matrix algebra and numerical analysis, solving ordinary differential equations.

Corequisite(s): BMEN 2021.

BMEN 2021 Computing Concepts & App. Lab (0)
Lab for ENGP 2020

BMEN 2310 Product & Experimental Design (3)
The objective of this course is to introduce students to the design process as they are starting the BMEN Curriculum. Through team projects geared toward translating bench research into product development, students will be challenged to begin thinking critically and applying physical fundamentals to complex systems. Weekly lectures will highlight phases of the design process, including problem identification, conceptual design, and early prototyping. Additionally, in the context of product and experimental design, students will gain experience with computer aided design and be provided an introduction to statistics. Course restricted to BMEN majors, or by permission of the instructors.

Corequisite(s): BMEN 2311.

BMEN 2311 Product & Experimntl Dsgn Lab (0)
Lab section for BMEN 2310

BMEN 2600 Intro Organic & Biochem (3)
This course introduces the main principles of Organic Chemistry and Biochemistry, preparing the student for BMEN 3030/3040. Topics include nomenclature of organic compounds and bio-molecules, major reactions 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.

Prerequisite(s): CHEM 1080 and (CHEM 1085 or 1180).

BMEN 2730 Biomedical Electronics (4)
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.

Prerequisite(s): ENGP 2010.
Corequisite(s): BMEN 2731.

BMEN 2731 Biomedical Electronics Lab (0)
Lab section for BMEN 2730.

Corequisite(s): BMEN 2730.

BMEN 2890 Service Learning (0-1)
Students complete a service activity in the community in conjunction with the content of a three-credit co-requisite course. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 2940 Transfer Coursework (0-20)
Transfer Coursework at the 2000 level. Department approval may be required.

Maximum Hours: 99

BMEN 3030 Anatomy & Physio for Engr (3)
This course is a single semester course in human structural anatomy. Course participants will examine both typical and pathological examples for the various subsystems including body tissues; the musculoskeletal; neurological; cardiovascular; respiratory; digestive; and reproductive systems.

Prerequisite(s): CELL 1010 or EBIO 1010.
Corequisite(s): BMEN 3035.

BMEN 3035 Anatomy & Physiology for Engineers Cadaver Lab (1)
This single-semester laboratory coordinates hands on learning in human structural anatomy. Course participants will dissect and examine both typical and pathological examples for the various subsystems including body tissues; the musculoskeletal; neurological; cardiovascular; respiratory; digestive; and reproductive systems.

Corequisite(s): BMEN 3030.

BMEN 3070 Quantitative Physiology (3)
This course places emphasis upon the chemical basis of life; cells and cellular metabolism; histology and tissues; the endocrine, skeletal and nervous systems; respiratory, digestive, cardiovascular, lymphatic and reproductive systems; nutrition and metabolism; water, electrolyte and acid-base balance, and human growth and development.

Prerequisite(s): CHEM 1070, 1080, CELL 1010 and BMEN 2600.
Corequisite(s): BMEN 3075.

BMEN 3075 Quant. Physiology Lab (1)
Subject matter will include blood, nutrition, and metabolism; and the cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems.

Corequisite(s): BMEN 3070.

BMEN 3400 Biomaterials & Tissue Engineering (3)
This course will focus on fundamental materials science and biological principles that impact the engineering design of biomaterials and tissue-engineered products. Topics addressed will include structural hierarchies of materials and tissues, physical and chemical properties of surfaces, degradation of materials, and cell-surface, cell-cell, and cell-matrix interactions. The course will conclude with inflammatory, immunological, and pathological events associated with responses to such products. Laboratory exercises will be utilized to illustrate selected concepts, introduce assessment methods, and provide hands-on experiences with cells and materials. Fulfills departmental domain requirement. An additional non-graded once a week lab section to accompany lectures.

Prerequisite(s): CELL 1010, ENGP 3120 and BMEN 2600.
Corequisite(s): BMEN 3401.

BMEN 3401 Biomaterials & Tissue Engineering Lab (0)
Lab section for BMEN 3400

BMEN 3440 Biofluid Mechanics (3)
This class focuses on fundamental concepts and properties of fluid mechanics with applications to the body. Topics to be covered include basic equations of fluid statics, dynamics and mass transport in differential and integral form using both system and control volume viewpoints. Rheological properties of biological fluids are studied as well as dimensional analysis and similitude. Advanced applications are investigated using the finite element method.

Prerequisite(s): ENGP 1410, 2430 and MATH 2240.

BMEN 3650 Biomechanics and Biotransport (3)
This course introduces students to biomechanics and biotransport. Specific topics include: the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials; the relationship between structure and function in tissues and organs. These topics will be related to fundamental principles of fluid mechanics and mass transport of biological systems at the cellular, tissue, and organ levels including cell adhesion and migration; intracellular, transmembrane and transvascular transport; drug transport and pharmacokinetics. Fulfills departmental 'domain" requirement.

Prerequisite(s): ENGP 2430 and BMEN 3440.
Corequisite(s): BMEN 3651.

BMEN 3651 Biomechanics & Biotrans Lab (0)
Lab section for BMEN 3650.

Corequisite(s): BMEN 3650.

BMEN 3730 Biomedical Signals and Systems (3)
Fundamentals of biomedical Signals and analysis and introduction to control systems. Topics include Laplace and Fourier transforms, the convolution theorem, time- and space-frequency-domain analysis, signals and noise, the mathematics of imaging, and examples and applications to biomedical signals. The use of MATLAS and Simulink to analyze biomedical systems will be reinforced.

Prerequisite(s): BMEN 2020 and (ENGP 2010 or MATH 2240).

BMEN 3820 Math Analysis Bio Systms (3)
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.

Prerequisite(s): MATH 2240.

BMEN 3890 Service Learning (0-1)
Students complete a service activity in the community in conjunction with the content of a three-credit co-requisite course. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 3932 Elements of BMEN Design (3)
This course develops the fundamental aspects of the mechanical performance of devices and components. Topics include a review of stress analysis, failure criteria, fatigue analysis and stress concentrations, as well as the mechanical behavior of fasteners, welded joints, spring selection, bearing design, and introduction to finite element analysis; with applications to biomedical engineering.

Prerequisite(s): ENGP 2430.

BMEN 3940 Transfer Coursework (0-20)
Transfer Coursework at the 3000 level. Department approval may be required.

Maximum Hours: 99

BMEN 4030 BMEN Team Dsgn Project I (2)
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, 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 assist an individual with a disability. These designs are presented in a public show during the second semester. Corequisite(s): BMEN 4031.

BMEN 4031 BMEN Team Design Project I Lab (0)
Lab section for 4030

BMEN 4040 BMEN Team Dsgn Proj II (3)
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, 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 assist an individual with a disability. These designs are presented in a public show during the second semester.

BMEN 4090 Spec Prob In Biomed Engr (1-4)
Independent study and investigation of special problems in biomedical engineering. Details can be arranged with individual biomedical engineering faculty members. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 4100 Spec Prob In Biomed Engr (1-4)
Independent study and investigation of special problems in biomedical engineering. Details can be arranged with individual biomedical engineering faculty members.

BMEN 4560 BME Professional Internship I (1-3)
Internship relevant to professional practice in biomedical engineering, 1-3 letter-graded credits (no S/U option), may count as credits towards graduation. May only be taken once.

BMEN 4570 BME Professional Internship II (1-3)
Internship relevant to professional practice in biomedical engineering, 1-3 credits graded S/U, may NOT count as credits towards graduation. May only be taken once.

Prerequisite(s): BMEN 4560.

BMEN 4660 Special Topics (1-3)
Special Topics. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 4890 Service Learning (0-1)
Students complete a service activity in the community in conjunction with the content of a three-credit co-requisite course. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 4900 Art of Professional Eng (1)
Research and Professional Practice (RPP) is a 2-semester sequence beginning in Spring of the Junior year. It satisfies the University's "Writing Intensive" requirement. A lecture series in the Spring semester, called "Art of Professional Engineering" includes economic analysis, ethics, professional communication including writing and oral presentation, research techniques including literature searching, citation, and the structure of a scientific paper. Students must also register for either 4901 or 4902 in the Spring semester, and continue the sequence with 4911 or 4912/4930 in the following Fall semester.

BMEN 4902 SR Research Prof Experience I (2)
This two-course sequence is designed to facilitate an individual biomedical research or design experience in a laboratory. Students will be intorduced to the tools, techniques, and rules necessary to function independently and professionally as a researcher or engineer. Topics include thesis writing, technical communication, and time management. The main component of the course is a two semester long research or design project under the direction of a faculty member, scientist or other professional. The course sequence culminates in a formal written report and Senior Research Conference presentation.

Prerequisite(s): BMEN 4900.

BMEN 4912 SR Research Prof Experience II (2)
This two-course sequence is designed to facilitate an individual biomedical research or design experience in a laboratory. Students will be intorduced to the tools, techniques, and rules necessary to function independently and professionally as a researcher or engineer. Topics include thesis writing, technical communication, and time management. The main component of the course is a two semester long research or design project under the direction of a faculty member, scientist or other professional. The course sequence culminates in a formal written report and Senior Research Conference presentation.

Prerequisite(s): BMEN 4902.

BMEN 4920 Senior Research and Design Conference (0)
This course is for seniors who have completed projects in Research and Professional Practice or Grand Challenges. Students will be required to give a 15 minute formal podium presentation to faculty, peers, and guests as the culmination of their year-long research or design project. This public presentation will be part of a professionally-styled senior-class conference at the beginning of the spring semester. Students may also be expected to attend invited seminars on an as needed basis. While this course carries 0 credit hours, satisfactory completion is a graduation requirement, commensurate with earning an accredited degree in biomedical engineering.

Prerequisite(s): BMEN 4911 or 4912.

BMEN 4940 Transfer Coursework (0-20)
Transfer coursework at the 4000 level. Departmental approval required.

Maximum Hours: 99

BMEN 5380 Study Abroad (1-20)
Courses taught abroad by non-Tulane faculty. Does not count toward Tulane GPA. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 5390 Study Abroad (1-20)
Courses taught abroad by non-Tulane faculty. Does not count toward Tulane GPA. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 6010 Physical Dimen of Aging (3)
This course is designed to introduce students to the physiological, behavioral, and socio-economic changes associated with aging. In particular, we will focus on the effects of exercise on the aging human system. We will also discuss what it means to become older within a community, what can a person expect during the aging process, and what kind of control a person has over his/her aging body.

Prerequisite(s): CELL 1010 or EBIO 1010.

BMEN 6030 Anatomy & Physio for Engr (3)
This is a single-semester course in human structural anatomy. Course participants will examine both typical and pathological examples for the various subsystems including, body tissues; the musculoskeletal, neurological, cardiovascular, respiratory, digestive and reproductive systems.

Corequisite(s): BMEN 6035.

BMEN 6035 Anatomy & Physiology for Engineers Cadaver Lab (1)
This single-semester laboratory coordinates hands-on learning in human structural anatomy. Course participants will dissect and examine both typical and pathological examples for the various subsystems including, body tissues; the musculoskeletal, neurological, cardiovascular, respiratory, digestive and reproductive systems.

Corequisite(s): BMEN 6030.

BMEN 6060 Biomedical Acoustics (3)
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.

Prerequisite(s): PHYS 1310 and 1320.

BMEN 6070 Quant Physio Lec (3)
Tulane University Health Sciences Center Staff. This course places emphasis upon the chemical basis of life; cells and cellular metabolism; histology and tissues; the endocrine, skeletal and nervous systems; respiratory, digestive, cardiovascular, lymphatic and reproductive systems; nutrition and metabolism; water, electrolyte and acid-base balance, and human growth and development.

Corequisite(s): BMEN 6075.

BMEN 6075 Quant. Physiology Lab (1)
Subject matter will include blood, nutrition, and metabolism; and the cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems.

Corequisite(s): BMEN 6070.

BMEN 6080 Tech Invent &Commercialization (3)
This course models innovation and entrepreneurial theory and practices from across a range of commercial size-scales, from small startup companies to intrapreneurial units within large, established companies. The twin poles of theory and practice are balanced through classroom lectures and experiential training. Weekly lectures furnish students with effective and portable theoretical frameworks for identifying, selecting and executing opportunities for technological innovations in healthcare, energy, water and the environment. In the experiential training, students will apply their classroom learning to targeted innovation and entrepreneurship opportunities within these sectors. Completion of this course will supply students with intellectual groundwork and practical experience in advancing inventive technological ideas towards commercialization and ultimately public benefit.

BMEN 6170 Biomedical Optics (3)
The field of biophotonics is a rapidly-expanding re-search area in which the interactions of photons with matter are leveraged to increase our understanding of biology and to improve the outcomes in human medicine. The objectives of this course are to familiarize students with the fundamental interactions between light and biological samples, and how these are implemented in an array of technologies that are finding successful application in biomedical research and clinical application. Topics will include fundamentals of photon transport in turbid media; optical spectroscopy variants (reflectance, fluorescence, Raman; steady-state and time-resolved); diffuse optical imaging; biological microscopy; coherence techniques; hybrid technologies (e.g. photo-acoustic imaging); and optical molecular imaging. Special attention will be paid to quantitative methods for spectroscopy and imaging in solid tissues. The class will be composed of lectures, and interactive discussions on recent papers representing the state of the art in the field.

BMEN 6220 Neural Microengineering (3)
In recent years, a number of technologies have been developed and utilized for probing the nervous system. This course will focus on microscale tools, technologies, and techniques employed for the control, manipulation, and study of the nervous system in vitro. Course material will be presented primarily by students who prepare presentations from extensive background literature review. A number of projects will be assigned as design challenges in which multiple interdisciplinary groups will research and present proposed solutions to the same challenge. Background in neuroscience not required. Generally offered every other Spring.

BMEN 6260 Molec Princ Funct Biomatr (3)
Functional biomaterials are non-viable materials that have been designed or modified in order to elicit specific biological responses when interacting with human fluids, cells, tissues, or organs. This course will focus on chemical principles utilized in endowing polymeric materials with biological functionality for medical applications. Following a brief review of polymer properties with a focus on hydrogels, topics addressed will include attachment of proteins to materials, induction of cell-binding and differentiation, responsive polymers, and spatial and temporal control of material properties for biological signaling. Unifying concepts will be introduced by directed reading and discussion of landmark papers in the biomaterials literature. Supplemental laboratory exercises will be utilized to illustrate selected concepts and introduce experimental procedures.

Prerequisite(s): BMEN 3400 or 6400.

BMEN 6310 Continuum Models In BMEN (3)
The course begins with a presentation of the kinematics of continuous media and elementary tensor manipulations. We will then cover the conservation principles of mass, linear momentum, angular momentum, and energy. Additional topics will include the formulation of constitutive laws, continuum models in electrodynamics, and simple descriptions of piezoelectric materials. These concepts will be applied to fundamental problems in bio-solid mechanics, bio-fluid mechanics, and bio-electromagnetism.

Prerequisite(s): (ENGP 2430, BMEN 3440 and 3650) or BMEN 6650.

BMEN 6330 Advanced Biofluid Mech (3)
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 6340 Soft Tissue Mechanics (3)
This course provides an introduction to the various approaches used in modeling 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.

Prerequisite(s): BMEN 3650 or 6650.

BMEN 6400 Biomaterials & Tissue Engineering (3)
This course will focus on fundamental materials science and biological principles that impact the engineering design of biomaterials and tissue-engineered products. Topics addressed will include structural hierarchies of materials and tissues, physical and chemical properties of surfaces, degradation of materials, and cell-surface, cell-cell, and cell-matrix interactions. The course will conclude with inflammatory, immunological, and pathological events associated with responses to such products. Laboratory exercises will be utilized to illustrate selected concepts, introduce assessment methods, and provide hands-on experiences with cells and materials. An additional non-graded once a week lab section to accompany lectures.

BMEN 6401 Biomaterials & Tissue Engr Lab (0)
Lab section for BMEN 6400

BMEN 6420 Transport in Cells and Organs (3)
Open only to graduate students. Fundamental principles of fluid mechanics and mass transport will be applied to biological systems at the cellular, tissue, and organ levels. The topics of this course will be the cardiovascular and respiratory systems; and cell adhesion and migration, intracellular, transmembrane and transvascular transport: drug transport and pharmacokinetics, and transport-related pathophysiological conditions (inflammation, atherosclerosis, thrombosis, sickle cell disease, cancer metastasis). The lab sessions will provide training in measurement and analysis of cell transport in parallel-plate flow systems.

BMEN 6421 Transport in Cells&Organs Lab (0)
Lab section for BMEN 6420

BMEN 6430 Vascular Bioengineering (3)
The objectives of this graduate-level course are to familiarize students with contemporary research areas that cover the field of vascular biology, and to provide an understanding of bioengineering principles related to physiological function and therapeutic modalities. Example topics include smooth muscle cell and endothelial cell lineage, leukocyte-endothelial cell interactions, angiogenesis, drug targeting via the microcirculation, neural vascular control, atherosclerosis, and hypertension. These topics will be presented in the context of four over-arching sections: 1) Vascular Cell Biology; 2) Principles of Vascular Function and Design; 3) Vascular Pathophysiology, and 4) Therapeutic Design. For each section of the course students will be required to read, critically analyze, and present relevant articles. As indicated by the section titles, the course will culminate by highlighting how our basic understanding of physiological function/dysfunction can be translated to therapeutic design.

BMEN 6440 Microphysiological Systems (3)
Microphysiological Systems (MPS) and organ-on-a-chip technology broadly refer to biologically-inspired engineered systems which integrate cells and 3D tissue constructs to model human physiology and disease in vitro. The term “chip” refers to fluidic culture devices that function in concert with other process control elements to emulate, manipulate, and monitor the biochemical activities, dynamic mechanical environments, and physiological responses of engineered human tissues, organs or organ systems. MPS engineering integrates multiple disciplines including design, microfabrication, cell culture technology, cellular physiology, tissue engineering, microelectromechanical systems, and human disease modeling. Course content covering these MPS foundations guides students through current literature reviews, interactive class discussions, and a semester-long MPS design project.

BMEN 6600 Comput Model Biomed Sys (4)
The objective of this graduate course is to provide students with the skills and knowledge necessary for computational modeling of biological and physiological systems. The first half of the course will cover introduction to UNIX, elements of programming (Matlab and FORTRAN), and numerical methods commonly used in biomedical research. The second half will immerse the students in specific biomedical applications including hemodynamics, respiratory flow, cellular mechanobiology, and neural dynamics. Most lectures will be accompanied by computer labs.

BMEN 6601 Comp Model Biomed Sys Lab (0)
Lab section for BMEN 6600.

Corequisite(s): BMEN 6600.

BMEN 6610 Intro Comp 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 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 6630 Cell Mechanics (3)
Fundamental principles of continuum mechanics will be applied to problems of biomechanics at the cellular level. Topics covered include structure of mammalian cells, cell membrane mechanics, mechanics of the cytoskeleton, models of cell viscoelasticity, cell adhesion, active cell processes, flow-induced deformation of blood cells, and experimental techniques (micropipette aspiration, biointerface probe, atomic force microscopy, magnetic twisting cytometry, optical tweezers, and flow chamber assays).

BMEN 6650 Biomechanics and Biotransport (3)
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.

Corequisite(s): BMEN 6651.

BMEN 6651 Biomechanics and Biotrans Lab (0)
Lab section for BMEN 6650.

Corequisite(s): BMEN 6650.

BMEN 6660 Special Topics (1-3)
Special Topics. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 6680 Orthopaedic Bioengineering (3)
Concentration on various engineering aspects of the human knee and the treatment of its common orthopaedic pathologies. Topics include histophysiology of wound healing, synovial joint anatomy and tissue biomechanics, knee biomechanics, osteochondral and ligamentous graft reconstruction, prosthetic ligaments, and knee arthroplasty with emphasis on the design issues involved and the integration of clinical practice. Prerequisites: ENGP 2430 and ENGP 3120, or graduate standing

Prerequisite(s): ENGP 2430 and 3120.

BMEN 6710 Departmental Seminar (1)
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 seniors and graduate students is required in the Fall semester. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 6730 Biomedical Signals and Systems (3)
Fundamentals of biomedical Signals and analysis and introduction to control systems. Topics include Laplace and Fourier transforms, the convolution theorem, time- and space-frequency-domain analysis, signals and noise, the mathematics of imaging, and exam

BMEN 6790 Design Studio (3)
This course is intended to provide students with a realistic design experience from virtual design, to rapid prototype fabrication, to testing, through redesign. It will focus on the practical application of leading commercial design software, including the creative extension of this software to innovate research applications. The course will be project intensive with commensurate report submissions and future design recommendations. Projects will include analyses of existing clinical problems, as well as research development of cell scaffolds and cell mechanotransduction.

Corequisite(s): BMEN 6791.

BMEN 6791 Design Studio Lab (0)
Lab for BMEN 6790.

Corequisite(s): BMEN 6790.

BMEN 6800 BME Data Science: Medical Imaging/Machine Learning (3)
The objective of this course is to teach graduate students the concepts, algorithms and programming of image processing and machine learning techniques and apply them to address real world biomedical imaging challenges. The basic image processing techniques such as image geometric transforms, Fourier analysis and linear systems theory will be introduced to model and process biomedical images. In addition, we will study some machine learning approaches such as feature extraction and classification for the analysis of biomedical image data. Finally, students will learn how to use MATLAB as a tool and apply the image processing and machine learning techniques to solve some medical imaging problems such as image enhancement, segmentation and classification.

BMEN 6820 Math Analysis Bio Systms (3)
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 6830 Intro Biomed Imaging & Process (3)
The objective of this course is to teach graduate students the concepts, algorithms and programming of image analysis techniques and apply them to address real world biomedical imaging challenges. The physics of medical imaging modalities including x-ray, MRI, CT, PET and microscopic imaging will be introduced. The basic underlying mathematical signal processing techniques such as Fourier analysis and linear system theory will be studied to model and process biomedical images. Finally, students will learn how to use MATLAB as a tool and apply the image processing techniques to solve some medical imaging problems such as image enhancement, segmentation and pattern classification.

BMEN 6840 Medical Imaging Physics (3)
This course will introduce imaging methods in medicine, including radiography, computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine (PET and SPECT), and ultrasound imaging. The basic physical principles of each imaging modality will be introduced, including the imaging energy source, properties and interaction with tissue. Basic concepts of image reconstruction will be discussed. This course will include laboratory visits to the School of Medicine Department of Radiology to explore real world uses of medical imaging systems. A course project will be assigned for students to assess new and emerging medical imaging systems.

Prerequisite(s): BMEN 3730 or 6730.

BMEN 6930 Special Topics (1-3)
The objective of this course is to introduce students to TRIZ (Russian acronym for "Theory of Inventive Problem Solving") a design method initially developed in the Soviet Union and used today by many Fortune 500 companies. TRIZ is an algorithmic approach to solving technical problems. In this course, students will learn and apply TRIZ principles to the design of technical systems in their area of interest-including but not limited to medical implant design, scientific research, and assistive device technology. Patent search and application of TRIZ to design around a patent also required.

Maximum Hours: 99

BMEN 6932 Elements of BMEN Design (3)
This course develops the fundamental aspects of the mechanical performance of devices and components. Topics include a review of stress analysis, failure criteria, fatigue analysis and stress concentrations, as well as the mechanical behavior of fasteners, welded joints, spring selection, bearing design, and introduction to finite element analysis; with applications to biomedical engineering. ·

BMEN 6940 Transfer Coursework (0-20)
Transfer coursework at the 6000 level. Departmental approval required.

Maximum Hours: 99

BMEN 6970 TRIZ - Theory of Inventive Design (3)
The objective of this course is to introduce students to TRIZ (Russian acronym for “Theory of Inventive Problem Solving”)—a design method initially developed in the Soviet Union and used today by many Fortune 500 companies. TRIZ is an algorithmic approach to solving technical problems. In this course, students will learn and apply TRIZ principles to the design of technical systems in their area of interest—including but not limited to medical implant design, scientific research, and assistive device technology. BMEN 6970 fulfills departmental design “domain” requirement for undergraduates; BMEN 6970 additionally requires patent search and application of TRIZ to “design around a patent.”

BMEN 7210 Direct Reads In BME Engr (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 7220 Direct Reads In BME (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 7320 Research In BME (1-6)
Individual research supervised by faculty.

Maximum Hours: 99

BMEN 7410 Research Methods (3)
Methods and resources for experimental studies in engineering science are introduced. Topics include the nature of scientific inquiry, literature search and writing techniques, experimental design and control, data analysis and presentation, and statistical methods. An original proposal is required.

BMEN 7560 Professional Internship I (1-3)
Internship relevant to professional practice in bioinnovation and biomedical engineering. 1-3 credits graded P/F. May only be taken once.

BMEN 7570 Professional Internship II (1-3)
Internship relevant to professional practice in bioinnovation and biomedical engineering. 1-3 credits graded P/F. May only be taken once (to follow Grad Pro Internship I).

BMEN 7940 Transfer Credit-Grad (1-12)
Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 9980 Master's Research (3)
Research toward completion of a masters degree. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

BMEN 9990 Dissertation Research (0)
Research toward completion of a doctoral degree. Course may be repeated unlimited number of times.

Maximum Hours: 99