M.S. in Bioengineering

Courses:

The curriculum requirements will be structured to be consistent with the prominent national M.S. Bioengineering programs, and with other M.S. engineering programs at NCAT. The M.S. program will require 24 course credits and 6 credits of thesis. Course requirements will have nine (9) credit hours of common core courses, nine (9) credit hours of engineering electives, and six (6) credit hours of life sciences electives in consultation with the advisor.

Core (9 credit hours)

BMEN 711 (PITT/BIOE 2810) Biomaterials and Biocompatibility Credit 3 (3-0)

This course serves as an introduction to biomaterials and biocompatibility and assumes some background in organic chemistry and biology. The first half of the course connects material chemical properties to performance issues relevant to biomaterial applications. The second part of the course introduces biocompatibility issues as they follow from protein adsorption. Thrombosis, inflammation, and infection are of primary interest. Throughout the course ties are made between the topic of study and clinically relevant material and device performance.

BMEN 712. Research Methods and Design of Experiments Credit 3 (3-0)

This course addresses research methods and protocols and introduces experimental designs and data analysis for research projects. Specific topics covered include Latin Squares, complete and incomplete block designs, one, two, and three variable factorials, fractional factorials, nested designs, and 2k designs will be covered. Prerequisite: Graduate Standing.

BMEN 713. Biotechnology Entrepreneurship Credit 3 (2-2)

This course introduces students to innovation and entrepreneurial skills development oriented toward a biotechnology and bioengineering enterprise. Topics covered include intellectual property development, technology transfer, evaluation of market viability, financing, marketing and operations. The course will also cover government regulations. Prerequisite: Graduate Standing.

BMEN 792 Seminar: Credit 0 (1-0)

This course will introduce students to current government regulations, industry practices, global issues, project management approaches and current issues in bioengineering. Lectures will also include biotechnology ethics. External speakers will be invited. Prerequisite: Graduate Standing.

Engineering electives (9 credit hours)

Biomaterials and Biomechanics

BMEN-685. Selected Topics in Bioengineering Variable Credit (1-3)

Selected engineering topics of interest to students and faculty. The topics will be selected before the beginning of the course and will be pertinent to the programs of the students enrolled. Prerequisite: Senior/Graduate Standing.

BMEN 732 (PITT/BIOE 2064) Biomechanics of Organs, Tissues, and Cells Credit 3 (3-0)

Modern biomechanics is an increasingly diverse field that encompasses the mechanics of the whole human body and all the way to the cellular and molecular levels. This comprehensive course covers the application of solid mechanics to describe the mechanical behavior of
organs, soft biological tissues, and cells. The course will include a review of fundamental concepts and techniques of mechanics (e.g. stress, strain, constitutive relations), and of the structure and composition of tissues and cells. The course will then focus on the mechanical properties of specific tissues, (e.g. tendon, muscle, heart, vascular) and cells (e.g. blood cells, valvular interstitial cells). Prerequisites: MEEN 702 or PITT/ME 2003 or equivalent.

BMEN 733 (PITT/BIOE 2067) Musculoskeletal Biomechanics Credit 3 (3-0)

This course will provide students with a detailed understanding of the structure and function of the tissues in the musculoskeletal system. Specific topics will include the kinematics, muscle forces and joint loads during human movement and the mechanics of the musculoskeletal connective tissues such as ligament, tendon, bone, cartilage and muscle. Special emphasis will be placed on the relationship between function and material properties of these tissues as revealed in the current scientific and engineering literature will be highlighted. A research paper that includes a computational analysis will be required as a term project.

BMEN 734 (PITT/BIOE 2072) Functional Tissue Engineering Credit 3 (3-0)

The design of engineered tissues involves both engineering and biological approaches. The focus of this course will be to introduce the student to the design of tissues from a Bioengineering perspective, with an emphasis on matching biomechanical behavior. For example, a mismatch in biomechanical properties between the cell/scaffold construct and the surrounding tissue can lead to catastrophic failure of an implant. Topics include review of extra-cellular matrix protein composition and structure, quantitative methods of tissue structural analysis, methods of biomechanical strength determination and basic modeling, scaffold composition, structure, and mechanical behavior, and utilization of in-vitro culture systems to obtain the desired structural and mechanical characteristics for long-term in vivo function.

BMEN 737 (PITT/BIOE 2620) Introduction to Tissue Engineering Credit 3 (3-0)

This course is designed to introduce students to an understanding of tissue engineering (TE), and the biomaterials, cells and growth factors used in TE. Specific applications include skin, nerve, bone, and soft tissue regeneration. Throughout the course ties are made between the topic of study and clinically relevant situations.

BMEN 835 (PITT/ BIOE 2515) Cardiovascular System Dynamics and Modeling Credit 3 (3-0)

The mechanical behavior of the cardiovascular system will be explored in a quantitative manner. The goal is to understand the behavior of each component in isolation and the interactions among various components. Mathematical modeling will be used with an emphasis on model development, validation, and application. The function of the intact organ will be correlated with underlying structural and cellular processes, both for normal and pathological states. Student projects will use (and contribute to) the existing library of cardiovascular models. Permission by instructor.

BMEN 736 (PITT/BIOE 2075) Advanced Biomaterials Credit 3 (3-0)

This course is designed to introduce students to a more advanced understanding of biomaterials used for reconstructive surgery. This includes skin, nerve, bone, and soft tissue regeneration. Biomaterials available for burn patients, cancer patients, and trauma patients are the central theme of this course. Throughout the course ties are made between the topic of study and clinically relevant biomaterial performance. Prerequisites: BMEN 711 or PITT/BIOE 2810 or equivalent.

BMEN-885. Advanced Special Topics in Bioengineering Credit 3 (3-0)

The course will address a current body of knowledge in Bioengineering with a research orientation. Term papers and projects will be required. Prerequisites: Graduate Standing and Consent of Instructor.

CHEN-605 Biochemical Engineering Credits 3 (3-0)

The course covers basic phenomena involved in biological systems, biochemical reaction systems, microbiology, and biological processes. Application of engineering methods to the design and control of biological systems. Biochemical production of industrial chemicals. Biological
waste treatment. Immobilized enzyme technology.

**CHEN-608 Bioseparations Credit 3 (3-0)**

The course is an introduction to the separation and purification of biochemicals. Separation processes are characterized as primarily removal of insolubles, isolation of products, purification or polishing. Processes covered include filtration, centrifugation, cell disruption, extraction, absorption, elution chromatography, precipitation, ultrafiltration, electrophoresis and crystallization. Students are required to complete a design project on a bioseparation process.

**CHEN-665. Introduction to Polymer Science & Engineering Credit 3 (3-0)**

This course is an introduction to the fundamentals of polymer science and engineering. Topics included are polymerization reaction mechanisms and kinetics, molecular weight distribution and measurement methods, crystallinity, morphology and phase transitions, structure-property relationships, solution properties and melt rheology. Commonly used polymer characterization techniques will be introduced. Industrial examples will be emphasized. Prerequisite: Senior standing in Chemical Engineering or permission of instructor.

**INEN-648. Biomechanics Credit 3 (3-0)**

This course covers human biomechanical and physiological behavior during work. Quantitative methods using engineering mechanics principles and computer simulation are emphasized. Prerequisite: Senior/Graduate Standing.

**INEN-812. Advanced Ergonomics Credit 3 (3-0)**

This course covers quantitative and qualitative analysis of human motions in space and time. Sample topics include human physiology, anthropometry, human figure modeling, and human performance for a set of task requirements and specifications. Design projects are required. Prerequisite: Graduate Standing.

**MEEN-650. Mechanical Properties and Structure of Solids Credit 3 (3-0)**

This course examines the elastic and plastic behavior of matter in relation to its structure, both macroscopic and microscopic. Major representative classes of materials to be examined are thermoplastic materials, elastomers, glasses, ceramics, metals, and composites. Prerequisite: MEEN 460 or equivalent.

**MEEN-702. Continuum Mechanics Credit 3 (3-0)**

This course covers the applications of the laws of mechanics and thermodynamics to the continuum. Topics include a rigorous development of the general equations applied to a continuum and the application and reduction of the general equations for specific cases of both solids and fluids. Prerequisite: MEEN 336 or equivalent.

**MEEN-716. Finite Element Methods Credit 3 (3-0)**

This course covers fundamental concepts of the finite element method for linear stress and deformation analysis of mechanical components. Topics include the development of truss, beam, frame, plane stress, plane strain, axisymmetric isoparametric, solid, thermal, and fluid elements. ANSYS and NASTRAN software will be used for solving practical stress analysis problems. Prerequisite: Consent of instructor.

**MEEN-719. Advanced Computer-Aided Design Credit 3 (3-0)**

This course covers important methods and techniques for using the computer to aid the design process. Simulation and optimization methods are applied to the design of mechanical systems. Prerequisite: Consent of instructor.
MEEN-808. Energy Methods in Applied Mechanics Credit 3 (3-0)

The use of energy methods in solving applied mechanics problems is presented in this course. Applications in beams and frames, deformable bodies, plates and shells, and buckling are addressed. Variational methods are also discussed. Prerequisite: MEEN 610 or equivalent.

MEEN-810. Advanced Theory of Elasticity Credit 3 (3-0)

This is a course in strains, stresses, and the equations of elasticity. Topics include general formulation of the 2-D boundary value problems and the formulation of certain three-dimensional problems with symmetry. Prerequisite: MEEN 610 or equivalent.

MEEN-813. Composite Structures Credit 3 (3-0)

This course focuses on the application of composite materials to the design and analysis of structures. The topics covered are two- and three-dimensional hydrothermal anisotropic elastic constitutive equations; classical laminate theory; static stress, vibration, and buckling analysis of laminated beams and plates; environmental effects; and fatigue and fracture of laminated composites. Prerequisite: MEEN 613 or equivalent.

MEEN-814. Mathematical Theory of Plasticity Credit 3 (3-0)

This course covers stress and strain tensors, transformations and equilibrium, and elastic behavior. Topics include: theories of strength, plastic stress/strain, classical problems of plasticity, including thick-walled pressure vessels and rotating cylinders in elastic-plastic conditions, and slip line theory with applications. Prerequisite: MEEN 610 or equivalent.

MEEN-858. Mechanical Metallurgy Credit 3 (3-0)

This course covers continuum mechanics and the microscopic basis of plastic behavior. Emphasis is on the development and use of dislocation theory. Prerequisite: Consent of instructor.

MEEN-860. Fracture Mechanics Credit 3 (3-0)

This course introduces the student to the concept of stress and strain singularities and their effect on fracture strength and fatigue life of isotropic and anisotropic materials. Topics covered include: computation of the stress-strain field around a crack-tip, stress-intensity-factor, strain energy release rate, J-integral, fracture toughness, residual strength, and fatigue crack propagation life. The course concepts are applied to the design of damage tolerant structures. Prerequisite: MEEN-460 or equivalent.

Bioimaging, Biosignals and Biosensors

BMEN-685. Selected Topics in Bioengineering Variable Credit (1-3)

Selected engineering topics of interest to students and faculty. The topics will be selected before the beginning of the course and will be pertinent to the programs of the students enrolled. Prerequisite: Senior/Graduate Standing.

BMEN 741 (PITT/BIOE 2380) - Medical Imaging Systems I Credit 3 (3-0)

A systems perspective introduction to the fundamentals of medical imaging techniques used to generate cross-sectional images of patients. Emphasis on use of multi-dimensional Fourier transforms to develop the generalized central-section theorem used in tomography at the imaging equation used in MRI. The critical concepts of image SNR and image quality will also be introduced. MRI and x-ray CT are used as two sample modalities to explore these basic concepts.
BMEN 842 (PITT/BIOE 2382) - Medical Imaging Systems II Credit 3 (3-0)

Intended for students with a background in linear systems and transforms (especially Fourier analysis), this course delves into the unique physical mechanisms of major medical imaging modalities: X-ray, MRI, Ultrasound, and Nuclear Medicine. Propagation of the underlying physics through the imaging process will be used to examine current research issues of selected modalities. Prerequisites: BIOE/EE 1380 (Medical Imaging Systems I) or equivalent, an introductory course in statistics and/or probability theory.

BMEN 843 (PITT/BIOE 2630) - Methods in Image Analysis Credit 3 (3-0)

The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Student will develop practical experience through projects using the National Library of Medicine Insight Toolkit (ITK), a new software library developed by a consortium of institutions including the University of Pittsburgh. In addition to image analysis, the course will describe the major medical imaging modalities and include interaction with practicing radiologists at UPMC.

BMEN 844 (PITT/BIOE 2600) – Neuroimaging Credit 3 (3-0)

This course consists of six state-of-the-art imaging techniques (i.e., MRI, MRS, fMRI, PET, MEG/EEG and Optical). Each part of the module will present in-depth analysis of the each technique and its application in neuroscience research. Apart from in-depth presentation of the each technique, students will also get acquainted with the operation of the respective instruments. Tour to that respective facility will be guided by the concerned faculty and scientific staff member in that respective facility will assist for demonstration.

BMEN-885. Advanced Special Topics in Bioengineering Credit 3 (3-0)

The course will address a current body of knowledge in Bioengineering with a research orientation. Term papers and projects will be required. Prerequisites: Graduate Standing and Consent of Instructor.

ELEN-606 Digital Electronics Credit 3(3-0)

This course covers analysis, design and applications of digital integrated circuits. These circuits may include resistor-transistor logic (RTL), diode transistor logic (DTL), transistor-transistor (TTL), emitter-coupled logic (ECL), metal-oxide-semiconductor (MOS) gates and n-channel MOS (NMOS) logic, complementary MOS (CMOS) logic, Bipolar CMOS (BiCMOS) structures, memory circuits, and interfacing circuits. Prerequisite: ELEN-460 or consent of instructor.

ELEN-608 Analog Electronics Credit 3(3-0)

This course covers the analysis, design and application of analog integrated circuits. These circuits may include operational amplifiers, voltage comparators, voltage regulators, Integrated Circuit (IC) power amplifiers, Digital to Analog (D/A) and Analog to Digital (A/D) converters, voltage-controlled oscillators, phase-locked loops, other special-function integrated circuits. Prerequisite: ELEN-460 or consent of instructor.

ELEN-650 Digital Signal Processing I Credit 3(3-0)

This course develops a working knowledge of the basic signal processing functions, such as digital filtering spectral analysis, and detection/post-detection processing. Methods of generating the coefficients for digital filters will be derived. Alternate structures for filters, such as infinite impulse response and finite impulse response will be compared. The effect of finite register length will be covered. Prerequisites: ELEN-400 or consent of instructor.

ELEN-657 Digital Image Processing Credit 3(3-0)

This course deals with concepts and techniques for digital image analysis and processing. Topics include image representation, image enhancement, edge extraction, image segmentation, geometric structure, feature extraction, knowledge representation, and image understanding. Prerequisite: ELEN-400 or consent of instructor.
ELEN-749 Digital Communications Credit 3(3-0)

The fundamental theory and applications of the digital communications system are discussed based on the knowledge of the probability theory. Topics in digital communications include sampling, quantizing, coding, detection, modulation/demodulation, signal-to-noise ratio, and error probability. Prerequisites: ELEN-449 or consent of instructor.

ELEN-849 Data Communications Credit 3(3-0)

This course is an extended study of digital communications. Various topics in the upper level of digital communications, such as channel coding, synchronization, multiplexing, multiple access, and frequency spreading are discussed. Prerequisite: ELEN-749 or consent of instructor.

ELEN-850 Digital Signal Processing II Credit 3(3-0)

This course deals with advanced topics in digital signal processing. Topics include the 2-D sampling theorem, the 2-D z-transform, the 2-D discrete Fourier transform, 2-D filters, and computational structures for the implementation of multi-dimensional digital signal processing algorithms. Prerequisite: ELEN-650 or consent of instructor.

ELEN-857 Pattern Recognition Credit 3(3-0)

This course covers classical topics in statistical decision function, Bayesian learning, error probability estimation, cluster-seeking, and deterministic approach. Several related topics are discussed, including stochastic approximation, feature selection and ranking, syntactic and structural pattern recognition. Prerequisite: ELEN-657.

ELEN-810 Theory and Techniques in Photonics Credit 3(3-0)

This course will concentrate on photonic materials such as semiconductors and oxide materials for opto-electronic integrated optic and nonlinear optic guided wave devices such as lasers, modulators and fibers. The course will also cover photonic systems for computing, communications, sensing, and data acquisition, processing and storage. Prerequisites: ELEN-450 or ELEN-470 and ELEN-602.

ELEN-865 Theory of Linear Systems Credit 3(3-0)

This course introduces modern control system design and analysis. Topics include linear-quadratic regulators, state estimators, and discrete-time control systems. Issues discussed include stability, robustness, and optimality. Prerequisites: ELEN-668 or equivalent.

Life sciences electives (6 credit hours)

Take six (6) credit hours from these elective courses:

BIOL-630. Molecular Genetics Credit 3 (3-0)

DNA and RNA structure, function and processing in prokaryotic and eukaryotic systems. Various aspects of recombinant DNA technology will be examined. Prerequisites: Biology 201 and 466.

BIOL-640. Introduction to Bioinformatics and Genomic Research Credit 3 (1-4)

The purpose of this course is to provide integrative experiences in computer and bench research in bioinformatics and genome science. Students will acquire hands-on experiences with web-based software and the tools research scientists are using to study the genomes of plants, microbes, humans and other organisms. They will input experimental data into one or more of these databases to perform genetic
analyses for making predictions about gene identity, structure, function, similarities and phylogenetic relationships. They will also use the databases to develop biochips, probes and primers for various laboratory applications. The integrative benchmark will involve testing results from database queries in the laboratory. This course will merge education and research and where possible engage students in investigative activities that involve collaborations with scientists on and off the campus. Prerequisites: BIOL 401 and BIOL 466. (F,S)

BIOL-650. Frontiers in Molecular Biology Credit 4 (2-4)

This course focuses on the theory, methods and applications of recombinant DNA technology. It includes special topics in molecular, cellular and developmental biology. The laboratory will provide hands-on exposure to the polymerase chain reaction, gene sequencing, development of gene libraries and other techniques in molecular biology.

BIOL-671. Principles of Immunology Credit 3 (3-0)

A study of mammalian immune responses; particularly in humans. Special emphasis will be placed on the physiology, genetics, and regulation of immune responses. Interrelationships between nonspecific and specific immune reactions, humoral and cell-mediated immunity, effector cells, and diseases are also stressed; along with research and diagnostic methodologies. Prerequisites: Biology 221 and 466; Chemistry 221 and 222.

BIOL-704. Cell and Molecular Biology Credit 3 (3-0)

A course that integrates the most recent advances in molecular biology of structure and function in cells. Prerequisite: Biology 462.

BIOL-749. Recent Advances in Cell Biology Credit 3 (3-0)

A course designed to present recent trends concerning functions of organized cellular and subcellular systems. Current research as it relates to the molecular and fine structure basis of cell function, replication, and differentiation will be discussed.

BIOL-750. Microscopy Technique Credit 3 (1-4)

This course is designed to develop the skills required to prepare cells, tissue, and organs for microscopic observation and study. Lectures will emphasize central concepts in microscopy. Prerequisites: Biology 201 and 462. Biology 465 is recommended.

CHEN-730 Advanced Biochemical Engineering Credit 3 (3-0)

This course is the study of advanced topics in biochemical engineering and enzyme engineering, highlighting research trends. Modeling and optimization of biochemical systems are also covered, as well as the design and analysis of enzyme reactors and the use of enzymes in industrial, environmental and medical applications.

CHEN-651. General Biochemistry Credit 3 (3-0)

A study of modern biochemistry. The course emphasizes chemical kinetics and energetics associated with biological reactions and includes a study of carbohydrates, lipids, proteins, vitamins, nucleic acids, hormones, photosynthesis, and respiration. Prerequisites: Chemistry 431 and 442.

CHEN-652. General Biochemistry Credit 3 (3-0)

This is a companion laboratory to Chemistry 651. Experimentation will include isolation and characterization of biochemical substances as well as studies of physical properties. Students will be introduced to a variety of techniques including high performance liquid chromatography, electrophoresis, and centrifugation. Corequisite: Chemistry 651. Prerequisites: Chemistry 432 and 444.

CHEN-674. Computational Methods in Protein Modeling and Drug Design Credit 3(2-2)

This course introduces various computational chemistry methods involved in modeling macromolecular proteins and structure-based drug design. A hands-on approach will be taken with equal time being spent in class and the laboratory. The course includes homology modeling, ab initio threading methods to model proteins from sequence to three-dimensional structures, chemothetics and structure-based drug design methods such as QSAR and docking. Prerequisite: CHEM 673.
CHEM-756. Selected Topics in Biochemistry  Credit 3 (3-0)

A lecture course on advanced topics in Biochemistry.

MCEN 610 Biological Applications of Engineering Credits 3(3-0)

This course covers the application of engineering principles and methods to problems in medicine, the integration of engineering with biology, and the emerging industrial opportunities. Examples from a variety of engineering disciplines will be provided. The ethical concerns associated with some emerging life science applications will be explored. Lab experiments will be utilized in the course to provide hands-on experience with life science concepts. Required is a research paper on an emerging application of life science in engineering. Prerequisite: Senior or graduate standing in engineering or permission of instructor.

New Courses

BMEN-685. Selected Topics in Bioengineering Variable Credit (1-3)

Selected engineering topics of interest to students and faculty. The topics will be selected before the beginning of the course and will be pertinent to the programs of the students enrolled. Prerequisite: Senior/Graduate Standing.

BMEN 711 (PITT/BIOE 2810) Biomaterials and Biocompatibility  Credit 3 (3-0)

This course serves as an introduction to biomaterials and biocompatibility and assumes some background in organic chemistry and biology. The first half of the course connects material chemical properties to performance issues relevant to biomaterial applications. The second part of the course introduces biocompatibility issues as they follow from protein adsorption. Thrombosis, inflammation, and infection are of primary interest. Throughout the course ties are made between the topic of study and clinically relevant material and device performance.

BMEN 712. Research Methods and Design of Experiments Credit 3 (3-0)

This course addresses research methods and protocols and introduces experimental designs and data analysis for research projects. Specific topics covered include Latin Squares, complete and incomplete block designs, one, two, and three variable factorials, fractional factorials, nested designs, and 2k designs will be covered. Prerequisite: Graduate Standing.

BMEN 713. Biotechnology Entrepreneurship Credit 3 (2-2)

This course introduces students to innovation and entrepreneurial skills development oriented toward a biotechnology and bioengineering enterprise. Topics covered include intellectual property development, technology transfer, evaluation of market viability, financing, marketing and operations. The course will also cover government regulations. Prerequisite: Graduate Standing.

BMEN 732 (PITT/BIOE 2064) Biomechanics of Organs, Tissues, and Cells  Credit 3 (3-0)

Modern biomechanics is an increasingly diverse field that encompasses the mechanics of the whole human body and all the way to the cellular and molecular levels. This comprehensive course covers the application of solid mechanics to describe the mechanical behavior of organs, soft biological tissues, and cells. The course will include a review of fundamental concepts and techniques of mechanics (e.g. stress, strain, constitutive relations), and of the structure and composition of tissues and cells. The course will then focus on the mechanical properties of specific tissues, (e.g. tendon, muscle, heart, vascular) and cells (e.g. blood cells, valvular interstitial cells). Prerequisites: MEEN 702 or PITT/ME 2003 or equivalent.

BMEN 733 (PITT/BIOE 2067) Musculoskeletal Biomechanics  Credit 3 (3-0)

This course will provide students with a detailed understanding of the structure and function of the tissues in the musculoskeletal system. Specific topics will include the kinematics, muscle forces and joint loads during human movement and the mechanics of the musculoskeletal connective tissues such as ligament, tendon, bone, cartilage and muscle. Special emphasis will be placed on the relationship between
function and material properties of these tissues as revealed in the current scientific and engineering literature will be highlighted. A research paper that includes a computational analysis will be required as a term project.

BMEN 734 (PITT/BIOE 2072) Functional Tissue Engineering Credit 3 (3-0)

The design of engineered tissues involves both engineering and biological approaches. The focus of this course will be to introduce the student to the design of tissues from a Bioengineering perspective, with an emphasis on matching biomechanical behavior. For example, a mismatch in biomechanical properties between the cell/scaffold construct and the surrounding tissue can lead to catastrophic failure of an implant. Topics include review of extra-cellular matrix protein composition and structure, quantitative methods of tissue structural analysis, methods of biomechanical strength determination and basic modeling, scaffold composition, structure, and mechanical behavior, and utilization of in-vitro culture systems to obtain the desired structural and mechanical characteristics for long-term in vivo function.

BMEN 737 (PITT/ BIOE 2620) Introduction to Tissue Engineering Credit 3 (3-0)

This course is designed to introduce students to an understanding of tissue engineering (TE), and the biomaterials, cells and growth factors used in TE. Specific applications include skin, nerve, bone, and soft tissue regeneration. Throughout the course ties are made between the topic of study and clinically relevant situations.

BMEN 741 (PITT/BIOE 2380) - Medical Imaging Systems I Credit 3 (3-0)

A systems perspective introduction to the fundamentals of medical imaging techniques used to generate cross-sectional images of patients. Emphasis on use of multi-dimensional Fourier transforms to develop the generalized central-section theorem used in tomography at the imaging equation used in MRI. The critical concepts of image SNR and image quality will also be introduced. MRI and x-ray CT are used as two sample modalities to explore these basic concepts.

BMEN-694. Special Projects Variable Credit (1-3)

Study arranged on a special engineering topic of interest to student and faculty member, who will act as advisor. Topics may be analytical and/or experimental and encourage independent study. Prerequisite: Consent of the instructor. M.S. and Ph.D. Students Only

BMEN 792 Seminar: Credit 1 (1-0)

This course will introduce students to current government regulations, industry practices, global issues, project management approaches and current issues in bioengineering. Lectures will also include biotechnology ethics. External speakers will be invited. Prerequisite: Graduate Standing

BMEN-797. Master's Thesis Variable Credit 1-6

This course provides the student an opportunity to complete a piece of original research, of their choice, in bioengineering, under the supervision of a faculty advisor. Students are required to complete a thesis proposal and a final defense in accordance with departmental guidelines. Prerequisites: Graduate Standing in BMEN

BMEN-799. Continuation of Master's Project / Thesis Credits 1 (1-0)

This course will enable master's students who have completed all required coursework and all project/thesis credits, to complete their project/thesis work. Prerequisites: Graduate Standing in BMEN

BMEN 835 (PITT/ BIOE 2515) Cardiovascular System Dynamics and Modeling Credit 3 (3-0)

The mechanical behavior of the cardiovascular system will be explored in a quantitative manner. The goal is to understand the behavior of each component in isolation and the interactions among various components. Mathematical modeling will be used with an emphasis on model development, validation, and application. The function of the intact organ will be correlated with underlying structural and cellular processes, both for normal and pathological states. Student projects will use (and contribute to) the existing library of cardiovascular models.
BMEN 836 (PITT/BIOE 2075) Advanced Biomaterials Credit 3 (3-0)

This course is designed to introduce students to a more advanced understanding of biomaterials used for reconstructive surgery. This includes skin, nerve, bone, and soft tissue regeneration. Biomaterials available for burn patients, cancer patients, and trauma patients are the central theme of this course. Throughout the course ties are made between the topic of study and clinically relevant biomaterial performance. Prerequisites: BMEN 731 or PITT/BIOE 2810 or equivalent.

BMEN 842 (PITT/BIOE 2382) - Medical Imaging Systems II Credit 3 (3-0)

Intended for students with a background in linear systems and transforms (especially Fourier analysis), this course delves into the unique physical mechanisms of major medical imaging modalities: X-ray, MRI, Ultrasound, and Nuclear Medicine. Propagation of the underlying physics through the imaging process will be used to examine current research issues of selected modalities. Prerequisites: BIOE/EE 1380 (Medical Imaging Systems I) or equivalent, an introductory course in statistics and/or probability theory.

BMEN 843 (PITT/BIOE 2630) - Methods in Image Analysis Credit 3 (3-0)

The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Student will develop practical experience through projects using the National Library of Medicine Insight Toolkit (ITK), a new software library developed by a consortium of institutions including the University of Pittsburgh. In addition to image analysis, the course will describe the major medical imaging modalities and include interaction with practicing radiologists at UPMC.

BMEN 844 (PITT/BIOE 2600) – Neuroimaging Credit 3 (3-0)

This course consists of six state-of-the-art imaging techniques (i.e., MRI, MRS, fMRI, PET, MEG/EEG and Optical). Each part of the module will present indepth analysis of the each technique and its application in neuroscience research. Apart from in-depth presentation of the each technique, students will also get acquainted with the operation of the respective instruments. Tour to that respective facility will be guided by the concerned faculty and scientific staff member in that respective facility will assist for demonstration.

BMEN-885. Advanced Special Topics in Bioengineering Credit 3 (3-0)

The course will address a current body of knowledge in Bioengineering with a research orientation. Term papers and projects will be required. Prerequisites: Graduate Standing and Consent of Instructor.

Facilities and Equipment

The program is supported by existing facilities and equipment in the University’s Interdisciplinary Institutes, Centers, and Programs. In addition, funds are available to establish new laboratories. The university is also committing space to house the department offices and instructional laboratories.

Existing Laboratory Facilities

High Performance Computing Systems

The following high performance and parallel computing resources along with their system, compiler and hardware resources are available for
the Ph.D. program. Further upgrading are planned with the establishment of the Ph.D. program. The computer hardware available are:

- 32 processor SGI 3900 systems with 32 GB memory and 1TB disk space (a shared memory architecture system) with system software and compilers.
- 18 node 36 process IBM Linux cluster (a distributed memory cluster)
- 8 processor SGI Altix

**Scientific Visualization Laboratory**

The scientific visualization laboratory has several end-user systems based on Windows, Linux and SGI Irix to meet the graphical visualization needs of the students. The laboratory houses a 6 projector stereo immersive visualization system. Additional equipment includes the color and black white printers. Several visualization software (AVS, Ensight, Paraview, VTK, etc) are also available to meet the diversified needs of both the applications and graphical developments.

**Center for Advanced Materials and Smart Structures (CAMSS)**

This center focuses on experimental, analytical and computational research in several aspects of material sciences and innovative material and sensor systems. The facilities include morphological facilities with high powered electron microscopes (Scanning Electron Microscope), Atomic Force Microscope (AFM), X-Ray Diffraction, etc., that complement the computational material science focused research. Doctoral students with research activities in the areas of computational material science and mechanics will have access to these facilities and faculty expertise available with the CAMSS center. The Center is headquartered at NCAT in the Fort Interdisciplinary Research Center (IRC). Materials laboratories occupy 10,000 sq. ft. of this building. The twelve current labs and facilities are interconnected and span 3 of the 5 floors of this building, providing a seamless state-of-the-art materials research infrastructure valued at over $6 M ([http://camss.ncat.edu](http://camss.ncat.edu)). The IRC supports a highly advanced cyber-infrastructure, Materials Processing and Sample Preparation, Electron Microscopy, Bio-Polymeric Smart Materials, Surface Characterization and Microscopy, XRD, Physical Property Measurement, and Mechanical Testing Laboratories. The interconnectedness and the open-door state-of-the-art research facility create a hub for interdisciplinary knowledge sharing that is critical for bioengineering discipline.

**Pulsed Laser Deposition Facility**

- Lambda Physik COMPex 201 Laser and optics tables, 18" dual Beam Chamber, Target
- Carrousell Flange Assembly, 3” Programmable Substrate Heater, turbo- and MD4 membrane pump, TCP600 speed controlling power supply

**Physical Vapor Deposition Laboratory**

- AJA ATC 1800-F Magnetron Sputtering System
- Vactronic Vacuum Thermo Evaporation System
- KLA-TENCOR Alpha-Step IQ Surface Profiler

**Nano-Materials and Composite Processing Laboratory**

- Computer controlled syringe pumping station
- Computer controlled high temperature Resin Transfer Molding fixture
- Reversible High shear mixer
High frequency Sonicator

Catalyst Laboratory

CAI NDIR Analyzer with CO/CO2 Modules
Polymer Materials Laboratory
Brabender Twin-Screw Polymer Prep-Center
Parr Instruments 4523 Polymerization Reactor
TA Instruments Q-100 Differential Scanning Calorimeter
Specialty Coating Systems G3P Spin Coater
Dynisco LCR 7001 Polymer Melt Rheometer
Barnstead Thermolyne 1300 Furnace
Perkin Elmer TGA-7 Thermogravimetric Analyzer
Waters 410 Gel Permeation Chromatography System
Hewlett-Packard 5890 Inverse Gas Chromatography System
Dynisco Polymer Melt Indexer
Keithley Model 6517A High Resistance Electrometer

Electron Microscopy / EDS Laboratory

Hitachi S-3000N Variable Pressure SEM with Chamberscope and Backscatter Detector
Oxford ISIS 310 EDS
Hitachi H-600AB Transmission Electron Microscope (100 keV)
Polaron SEM Coating System
Fischione 1010 Low Angle Ion Milling Machine
VCR Group Inc. D500i Dimpler

Nanoengineering Laboratory

MTS Nanoindenter XP with Continuous Stiffness Measurements and Test Works 4 System
Nano-R Atomic Force Microscope
CETR Microtribometer
WYKO RST 500 Optical Profiler

X-ray Diffraction Facility

Bruker D8 Advance X-ray Diffractometer with DHS 900 Domed Hot Stage (up to 900 °C) and Eurlean Cradle
Microscopy and Sample Preparation Laboratory
Zeiss MC-100 Optical Microscope with Insight CCD Camera
Nikon Epiphot Inverted Microscope with CCD Camera
Meiji Optical Microscope with Large Format Photomicrographic Camera PMX100
Polaroid MP-4 Camera System
Various sample preparation equipment (LECO and Buehler)

Manufacturing Laboratory & Instrumentation and Controls Laboratory
AIP Hot Isostatic Press HIP6-30H (max pressure 30 ksi, max temperature 2200ºC)
Unitron 4003 toolmaker's microscope
Lathe, mill, surface grinder, force I torque dynamometers and accelerometers

Fuel Cell Facility
Solid Oxide Fuel Cell combustion chemical vapor deposition setup

Mechanical Testing Laboratory
MTS 311 (110 kip) Mechanical Testing Frame with Instron High Capacity Grips
Instron 5542 (112 lb) Single Column Fiber Test System
Instron Dynatup 8250 Low Velocity Impact Test System
Leco M-400-H1 Microhardness Tester
Rockwell Hardness Tester

High-Temperature Materials Laboratory
Instron 8511 (9.2 kip) High Temperature Fatigue System
ATS 1605 (1.0 kip) Series Four-Point Bend Test Machine with HT Furnace (1650ºC)
and Controller
MTS 880 Series (22 kip) Mechanical Testing Frame with MTS HT Furnace and Epsilon
HT Extensometer
Creep Set-up for Brittle Materials with Furnace (1600ºC) Lasermike Gaging