Biomedical Engineering

College of Engineering

The Department of Biomedical Engineering offers master's and doctoral degrees in addition to a minor in Biomedical Engineering. The graduate programs emphasize the application of engineering principles to the areas of medicine and biology and covers the broad aspects of mechanics, materials, fluids, optics, signal processing, systems analysis, instrumentation, physiology, cellular processes, and laboratory experimentation. Students in the program are provided with educational and research opportunities through the facilities and faculty of the Department and its ideal geographic location and close ties with other units of the University, ranging from engineering to basic science to clinical departments.

Areas of research include cardiac arrhythmia, cardiopulmonary control, magnetic resonance imaging, biomedical optics, orthopedic biomaterials and bone tissue engineering, and orthopedic biomechanics. The Department is housed in the centrally located Robotics and Manufacturing Building which makes it convenient for multidisciplinary research. Faculty and staff of the Department collaborate with investigators from other units of the University, including Anatomy & Neurobiology, Biochemistry, Biology, the Markey Cancer Center, Cardiovascular Medicine, Cardiothoracic Surgery, Center for Applied Energy Research, Chemical Engineering, Chemistry, Electrical Engineering, Mathematics, Mechanical Engineering, Neonatology, Nephrology, Neurosurgery, Oral Surgery, Orthopaedic Surgery, Otolaryngology, Pediatric Cardiology, Periodontics, Pharmacy, Physiology, and Plastic Surgery. Department faculty and staff provide opportunities and support for graduate students, medical residents, and selected undergraduates. Graduates of the program enter careers in research institutes, academia, hospitals, and the biomedical field.

Admission Requirements
Entering students are expected to have a baccalaureate degree in engineering. Some course work in the biological sciences is desirable but not required. Applicants with degrees purely in the physical or biological sciences may be required to complete select course work in the undergraduate engineering curriculum before being admitted to the graduate program. Admission to the biomedical engineering graduate program normally requires a GPA of at least 3.0/4.0 for all graduate and undergraduate work and Graduate Record Examination scores of ≥156 (Quantitative), ≥154 (Verbal) and ≥4.0 (Analytical). Additional application materials to be submitted to the Department include a statement describing your reasons for wanting to pursue graduate education in Biomedical Engineering and letters of recommendation from (3) faculty members who are familiar with your academic record. There is no specific form that is required for these letters. Satisfying the above requirements does not guarantee admission to the biomedical engineering graduate program.

Master of Science

The Master of Science degree provides students with a combination of experiences in basic research, design, development, and practical applications. The M.S. degree requires successful completion of the core curriculum (26 credit hours) plus an accepable thesis. In special cases, a non-thesis option consisting of 31 credit hours is available for students with significant previous research or design experience or those who are concurrently employed in a biomedical engineering related industry. Enrollment in the non-thesis option requires approval of the Director of Graduate Studies and must be requested within the student's first 9 credit hours of graduate course work.

Core M.S. Curriculum

BME 530	Biomedical Instrumentation	(3)
BME 605	Biomedical Signal Processing	(3)
BME 661	Biomaterials Science and Engineering	(3)
BME 6XX	Biomechanics Elective	(3)
BME XXX	BME Technical Elective	(3)
BME 772	Seminar	(0)
BME 640	Ethics in BME and Science	(1)
PGY 412G	Principles of Human Physiology	(4)
	Math Elective	(3)
	Technical Elective	(3)

Professional Master of Biomedical Engineering

The Professional Master of Biomedical Engineering degree seeks to develop a unique combination of managerial, technical and leadership skills for those who will direct the future course of biomedical technology. The P.B.M.E. degree requires successful completion of 42 credits, including the capstone Advanced Study Project, and a summer internship.

Core P.B.M.E. Curriculum

BME XXX	BME Technical Electives	(9)
BME 642	Navigational Guides for Biomedical Product Designs	(2)
BME 766	Advanced Study Project	(3)
BME 772	Seminar	(0)
BME 777	Advanced Study Project	(3)
HA 601	Healthcare System Overview	(3)
HA 602	Strategic Planning and Management of Healthcare Organizations	(3)
HA 621	Quantitative Methods of Research	(3)
HA 637	Health Finance	(3)
MKT 600	Marketing Management	(3)
PA 623	Decision Analysis	(3)
PA 642	Public Organ Theory and Behavior	(3)
PGY 412G	Principles of Human Physiology	(4)

Doctor of Philosophy

The Doctor of Philosophy is a research degree granted on the basis of broad knowledge of engineering applications in biology and medicine and an in-depth study in a specific area leading to a dissertation reflecting original and independent work by the candidate. Applicants to the Ph.D. program are generally expected to have a master's degree. Under special circumstances, exceptional students may bypass the M.S. and be admitted directly to the Ph.D. program upon approval of the biomedical engineering faculty. Courses for advanced study are determined in consultation with an advisory committee and will be selected from the areas of engineering, mathematics, life sciences, and chemistry.

To earn a Ph.D. degree, students must:

1. Meet the requirements of the Graduate School.
2. Succesfully complete PGY 502.
3. Pass the Qualifying Examination. This exam, consisting of written and oral components, is designed and administered by the student's Doctoral Advisory Committee.

4. Present and satisfactorily defend a dissertation documenting independent and comprehensive scholarship.

Further information about the graduate programs may be obtained by writing to the Director of Graduate Studies, Department of Biomedical Engineering, 522 RMB, 143 Graham Avenue, University of Kentucky, Lexington, KY 40506-0108, by e-mail at bmedgs@uky.edu, or by visiting our web site at http://www.engr.uky.edu/cbme/future-students/programs/phd/.

Course Descriptions

BME 501 FOUNDATIONS OF BIOMEDICAL ENGINEERING. (3)
This course demonstrates the application of diverse engineering principles to analysis and understanding of the structure, function, and control of biological systems. Quantitative measurements and analysis of homeostatic, regulatory, transport, biochemical, and biomechanical processes of the human body. Prereq: Engineering standing or consent of instructor.

BME 508 CELL MECHANICS AND MECHANOBIOLOGY. (3)
This course will serve as an introduction to cell and tissue level mechanobiology with focus on human physiological and disease processes. The primary focus is to introduce principles of cell-level mechanics in the context of the biology of living organisms, what we term mechanobiology. In effect, we treat biological processes and regulation as another variable(s) that must be accounted for when modeling the mechanical/physical behavior of human tissues. A large amount of the basic principles in this field of study arose as a result of the intense research in the cardiovascular field. We will draw many examples of mechanobiological principles as it relates to the circulatory system. Despite our cardiovascular focus, the basic principles can be applied to the whole range of mechanobiological research conducted in other applications (orthopedics, urological, pulmonary, etc.). Prereq: EM 302 and/or CME/ME 330 (or equivalent fluid mechanics course); or consent of instructor.

BME 515 MODELING OF PHYSIOLOGICAL SYSTEMS. (3)
This introductory course in mathematical modeling will teach students how to construct simple and elegant models of biological and physiological processes – for instance the absorption and elimination of drugs in the human body or the kinetics of tumour growth in tissue– and to analyze or predict the dynamics of these events by solving the models. Prereq: MA 113, 114, 213, 214, or consent of instructor; familiarity with computer programming.

BME 530 BIOMEDICAL INSTRUMENTATION. (3)
A comprehensive introduction to major aspects of biomedical instrumentation. Topics include basic concept of medical instrumentation, biopotentials, physiological pressure/flow/respiratory measurement, optical sensing, and clinical applications of all the above. The fundamental mathematics underlying each instrument will be reviewed and an engineering picture of the hardware and software needed to implement each system will be examined. Prereq: Consent of instructor.

BME 540 MECHANICAL MODELING OF HUMAN MOTION. (3)
An introduction to mechanical modeling of human motion (lectures) along with application of computational software to model and estimates internal tissues responses to physical demands of several different activities/tasks (lab activities). Prereq: EM 221, EM 313; or consent of instructor.

BME 541 OCCUPATIONAL BIOMECHANICS. (3)
This course will provide an understanding of physical interaction between workers and their tools, machines, and materials so as to enhance the workers performance while minimizing the risk of musculoskeletal disorders. Discussion of ergonomic methods for measurement, assessment, and evaluation, with major topics including manual materials handling, cumulative trauma disorders, environmental stresses, safety, and legal issues. Prereq: Engineering standing or with instructor permission. (Same as MFS 541.)

BME 579 NEURAL ENGINEERING: MERGING ENGINEERING WITH NEUROSCIENCE. (3)

A multidisciplinary approach combining engineering principles for systems analysis and control, knowledge of biological control mechanisms, and computational properties of biological neural networks in the development of engineering neural networks for control applications. Topics include: equivalent circuit models for biological neurons and networks, non-linear differential equation representations, biological control strategies for rhythmic movements, design and development of controller for robot function, proposal development and presentation. Prereq: EE 422G and Engineering Standing or consent of instructor. (Same as EE 579.)

BME 580 INTRODUCTION TO BIOMEDICAL IMAGING. (3)
A comprehensive introduction to bio-medical imaging systems used today, including xray imaging and computed tomography (CT), magnetic resonance imaging (MRI), ultrasound imaging (UI), and diffuse optical tomography (DOT). The course will review the fundamental mathematics underlying each imaging modality, the hardware needed to implement each system, and the image reconstruction and analysis. The class may involve homework, projects, and exams. Prereq: EE 305, or consent of instructor.

BME 599 TOPICS IN BIOMEDICAL ENGINEERING (Subtitle required). (3)
An interdisciplinary course devoted to detailed study of a topic of current significance in biomedical engineering, such as cellular mechanotransduction, systems biology, and tissue engineering. May be repeated to a maximum of six credits. Prereq: Consent of instructor.

BME 605 BIOMEDICAL SIGNAL PROCESSING I. (3)
Continuous and discrete signals, sampling, Fourier Transform, LaPlace Transform, Z-Transform, correlation and spectral analysis, digital filters. Prereq: Concurrent enrollment or completion of PGY 412G or PGY 502.

BME 610 BIOMEDICAL CONTROL SYSTEMS I. (3)
Homeostatic mechanisms, input-output analysis, steady state and transient response, feedback concepts, system identification and simulation from actual operating data. Prereq: PGY 502 and ME 440 or equivalent.

BME 615 BIOMEDICAL SIGNAL PROCESSING II. (3)
Stochastic processes, Fourier-based spectral analysis and linear system identification, modern spectral estimation (AR, MA, ARMA), parametric transfer function estimation, time-frequency analysis of nonstationary signals. Prereq: BME 605, BME 610, EE 640 recommended.

BME 640 BIOMEDICAL ENGINEERING ETHICS. (1)
This course presents an engineering-based approach to study the system of ethics applicable to biomedical engineering. This course will describe and examine the responsibilities of biomedical engineers to stakeholders, e.g., patients, research subjects, and engineering clients as well as to the legal system (where applicable) and the profession as an entity. As a scholarly discipline, biomedical engineering ethics draws upon principles from subjects such as: the philosophy of science, the philosophy of engineering, and the ethics of technology. Materials from these principles will be used in this course with adaption to the special circumstances attending the practice of Biomedical Engineering.

BME 642 NAVIGATIONAL GUIDES FOR BIOMEDICAL PRODUCT DEVELOPMENT. (3)
This course teaches engineers how biomedical product designs are influenced by government regulations, economic issues, and ethicalconcerns.

BME 661 BIOMATERIALS SCIENCE AND ENGINEERING. (3)

Study of biological and man-made materials that perform, improve, or restore natural functions. Structure and properties of connective tissue and commonly implanted metals, ceramics, and polymers; biocompatibility of materials used in orthopedic, soft tissue, and cardiovascular applications. Prereq: Undergraduate engineering degree or consent of instructor.

BME 662 TISSUE-IMPLANT INTERFACE. (3)
Study of the interface between implants and host tissues from both the materials and biological perspective. Structure of the tissue-implant interface; surface characterization of biomaterials; protein adsorption; mechanisms of cell responses; the methods for controlling the tissue-implant interface, with emphasis on orthopedic and cardiovascular applications. Prereq: BME 661 or consent of instructor.

BME 670 BIOSOLID MECHANICS. (3)
Application of laws of mechanics to study the behavior of human organ systems. Stress-strain analysis of soft and hard body tissues with emphasis on pulmonary and musculoskeletal systems. Viscoelastic properties. Prereq: Undergraduate engineering degree or consent of instructor.

BME 672 MUSCULOSKELETAL BIOMECHANICS. (3)
Application of laws of mechanics to study behavior of human musculoskeletal system. Materials science of bone, muscle, tendon are integrated into static and dynamic analyses of isolated (e.g., foot, arm, and hand) and whole body segment. Prereq: PGY 502, ME 330 or consent of instructor.

BME 685 BIOFLUID MECHANICS. (3)
Review of the rheology of circulatory processes in the body. Special emphasis on cardiovascular dynamics: pulsatile pressure and flow, vascular impedance, wave propagation/reflection, cardiac dynamics. Special topics. Lecture, three hours with periodic lab demonstrations. Prereq: Undergraduate engineering degree or consent of instructor.

BME 690 RESEARCH IN BIOMEDICAL ENGINEERING (Subtitle required). (1-3)
Individual study related to a special research project. Intended for M.S. candidates who want a research project experience independent of their M.S. thesis work. This course cannot be used to satisfy residency credit requirements. Lecture, 1-3 hours; laboratory, 3-6 hours per week. May be repeated to a maximum of six credits. Prereq: Consent of instructor and graduate standing in BME.

BME 699 SPECIAL TOPICS IN BIOMEDICAL ENGINEERING (Subtitle required). (1-3)
Special topics in biomedical engineering, addressed primarily in a lecture/discussion format. Presentation of focussed or specialized topics that are not available in standard courses. Lecture, three hours; laboratory 0-2 hours per week. May be repeated to a maximum of nine credits. Prereq: Consent of instructor and graduate standing in BME.

BME 748 MASTER'S THESIS RESEARCH. (0)
Half-time to full-time work on thesis. May be repeated to a maximum of six semesters. Prereq: All course work toward the degree must be completed.

BME 749 DISSERTATION RESEARCH. (0)
Half-time to full-time work on dissertation. May be repeated to a maximum of six semesters. Prereq: Registration for two full-time semesters of 769 residence credit following the successful completion of the qualifying exams.

BME 766 MANAGEMENT OF TECHNOLOGY. (3)

Successfulness in developing new technologies relies upon knowing which technology advance, the ultimate scientific limits of that technology, and the forecasted rate of technological change. This course presents curricula that explore the direction of technological change and how this affects the rate and extent of innovation.

BME 767 DISSERTATION RESIDENCY CREDIT. (2)
Residency credit for dissertation research after the qualifying examination. Students may register for this course in the semester of the qualifying examination. A minimum of two semesters are required as well as continuous enrollment (Fall and Spring) until the dissertation is completed and defended.

BME 768 RESIDENCE CREDIT FOR THE MASTER'S DEGREE. (1-6)
May be repeated to a maximum of 12 hours.

BME 769 RESIDENCE CREDIT FOR THE DOCTOR'S DEGREE. (0-12)
May be repeated indefinitely.

BME 772 SEMINAR. (0)
Review of current literature in the field of biomedical engineering, general discussion and presentation of papers on research in biomedical engineering. Lecture, one hour per week. Required for all graduate students in biomedical engineering.

BME 774 GRADUATE BME SEMINAR. (0-1)
Scientists and engineers present current research in biomedical engineering. Students are required to prepare for and deliver a seminar on their own research. May be repeated to a maximum of 4 credits. Prereq: Graduate standing in Biomedical Engineering or consent of instructor.

BME 777 ADVANCED STUDY PROJECT. (3)
This is an independent study project, topic to be selected in consultation with the instructor. Purpose is to integrate all materials learned in the program and apply these principles to the solution of an actual problem in biomedical engineering technology. Prereq: Permission of instructor and completion of year 1 PBME studies.

BME 781 SPECIAL PROBLEMS IN BIOMEDICAL ENGINEERING (Subtitle required). (1-3)
Discussion of advanced and current topics in biomedical engineering. Individual work on research problems of current interest. May be repeated to a maximum of nine credits. Lecture/laboratory hours, variable. Prereq: Approval of instructor.

BME 790 RESEARCH IN BIOMEDICAL ENGINEERING. (1-9)
Graduate research in any area of biomedical engineering, subject to approval of the Director of Graduate Studies. May be repeated to a maximum of nine hours. Prereq: Consent of the Director of Graduate Studies.