

## Biomedical Engineering

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### COLLEGE OF ENGINEERING

#### Master of Science (MS) in Biomedical Engineering

##### Electrical and Computer Engineering (ECE) Faculty:

**Anagnostopoulos, Iraklis**, Assistant Professor, Ph.D., National Technical University of Athens, 2014; 2015. Embedded biomedical systems.

**Chen, Ying (Ada)**, Associate Professor, Ph.D., Duke, 2007; 2007. Biomedical imaging, image reconstruction, digital tomosynthesis, image quality analysis, signal and image processing, simulation and computing.

**Gupta, Lalit**, Professor, Ph.D., Southern Methodist University, 1986; 1986. Computer vision, pattern recognition, digital signal processing, neural networks.

**Kagaris, Dimitrios**, Professor, Ph.D., Dartmouth College, 1994; 1995. VLSI design automation, digital circuit testing, communication networks.

**Montemagno, Carlo**, Professor and *Chancellor*, Ph.D., University of Notre Dame, 1995; 2017. Biotechnology, nanotechnology.

**Qin, Jun**, Assistant Professor, Ph.D. Duke University, 2008. Medical device development, instrumentation and sensors, medical data acquisition and analysis, medical acoustics, therapeutic ultrasound, haptics.

**Sayeh, Mohammad R.**, Professor and *Director*, Ph.D., Oklahoma State University, 1985; 1986. Neural networks, optical computing, image processing, stochastic modeling, quantum electronics.

**Wang, Haibo**, Professor, Ph.D., University of Arizona, 2002; 2002. Mixed-signal VLSI design and testing, digital VLSI, VLSI design automation.

##### Mechanical Engineering and Energy Processes

##### (MEEP) Faculty:

**Chowdhury, Farhan**, Assistant Professor, Ph.D., University of Illinois at Urbana-Champaign, 2011; 2015. Mechanobiology, single-molecule cell mechanics, biomaterials.

**Chu, Tsuchin P.**, Professor, Ph.D., University of South Carolina, 1982; 1990. Non-destructive evaluation, biomedical engineering, FEA, carbon composites, CAD/CAM, machine vision, optical methods in experimental mechanics, image processing and analysis.

Kim, Dal Hyung, Assistant Professor, Ph.D., Drexel University, 2013; 2017. Robotics, brain imaging, microscope design, optimal control, microbiotics.

**Filip, Peter**, Professor, Ph.D., Technical University Ostrava, Czech Republic, 1989; 2004. Friction materials, biomaterials.

##### Academic Objectives

The proposed program, consistent with the mission and priorities of the University, is designed to achieve the following academic objectives:

- To provide high quality education in the field of biomedical engineering and to prepare the graduates for successful and rewarding employment as engineers or for continuing their education through the doctoral level.

- To provide the students with the training necessary to successfully apply the fundamental concepts and methods of biomedical engineering to selected areas of employment or research and development.

- To enhance the research environment and productivity of the College of Engineering, and all other units participating in the program, for the benefit of the students.

##### Admission Requirements

Admission to the Biomedical Engineering Master of Science program is restricted to students with a Bachelor of Science degree in Biomedical Engineering, Computer Engineering, Electrical Engineering, Materials Engineering, Mechanical Engineering, or a related engineering field with a GPA of 3.25 / 4 or higher. Applications for admission must include the following: A statement of interest, transcripts, GRE scores, three reference letters and TOEFL score (where appropriate), as required by the Graduate School. The application fee for all applicants, and any other documentation specifically required for international students will be in accordance to the requirements of the Graduate School. Admission to the program is made by the Dean of Engineering (or his designee) upon recommendation by the Biomedical Engineering (BME) Program Committee.

##### Degree Requirements

The College of Engineering offers two different programs leading to the Master of Science degree in Biomedical Engineering, the Thesis and the Non-thesis program. The requirements for each of the programs are specified below.

The thesis program leading to the Master of Science degree in Biomedical Engineering requires at least 30 semester credit hours as follows: (1) Biomedical Engineering Foundation coursework totaling 9 semester credit hours, (2) at least 9 semester credit hours of Biomedical Engineering Core coursework, (3) 6 semester credit hours of thesis (BME 599), and (4) all remaining coursework should be selected from either the Biomedical Engineering Core or Biomedical Engineering Electives listings below, with no more than 6 semester credit hours at the 400-level.

The non-thesis program leading to the Master of Science degree in Biomedical Engineering requires at least 36 semester credit hours as follows: (1) Biomedical Engineering Foundation coursework totaling 9 semester credit hours, (2) at least 9 semester credit hours of Biomedical Engineering Core coursework, and (3) all remaining coursework should be selected from either the Biomedical Engineering Core or Biomedical Engineering Electives listings below, with no more than 6 semester credit hours at the 400-level.

##### Biomedical Engineering Foundation - 9 Semester Credit Hours

BME 485-3 Cellular and Molecular Biomechanics  
BME 596-3 Introduction to Biomedical Engineering  
ENGR 521-3 Probabilities and Random Variables

##### Biomedical Engineering Core – (at least 9 Semester Credit Hours)

BME 532-3 Biomedical Imaging  
BME 536-3 Biomedical Signal Modelling  
BME 538-3 Medical Instrumentation

BME 539-3 Biomechanics I  
 BME 540-3 Biomechanics II  
 BME 541-3 Diagnostic Ultrasound  
 BME 542-3 Biomaterials

**Biomedical Engineering Electives (no more than 6 Semester Credit Hours at 400-level)**

ME 465-3 Introduction to Nanotechnology  
 ME 472-3 Materials Selection for Engineering Design  
 ME 480-3 Computational Fluid Dynamics  
 ME 566-3 Advanced Mechanics Materials  
 ECE 558-3 Digital Image Processing I  
 ECE 572-3 Neural Networks  
 ECE 568-3 Pattern Classification  
 ECE 578-3 Digital Image Processing II

**Program Administration and Student Advisement**

The Biomedical Engineering (BME) Director is appointed by the Dean of the College of Engineering. The BME Director is responsible for student recruitment, initial advisement, graduation approvals, program outcomes assessment, and continuous program improvements. The BME Director works collaboratively with Chairs of the Electrical and Computer Engineering and the Mechanical Engineering and Energy Processes departments to effectively execute annual course offerings.

For any issue not specifically addressed, such as residency requirements, time limits, credit transfer, etc., please refer to the rules and regulations of the Graduate School, published in the graduate catalog.

**Program Outcomes**

The graduates from the MS and ME programs in Biomedical Engineering are expected to develop and demonstrate the following abilities:

- To successfully apply analytical methods (especially probability and statistics) and other engineering methods (e.g. modeling, stimulation and design) to solve important biomedical engineering problems
- To effectively communicate complex technical information with clear and concise language

**Biomedical Engineering (BME) Courses**

**BME 481-3 Design and Implementation of Vision System.** (Same as ME 481) This course provides an introduction to a vision system and instrumentation with engineering applications including optical microscopy. A vision system is an essential tool in most of the application, and optical microscopy is a powerful scientific tool to study microscale worlds. Topics covered in basic geometrical optics, Optoelectronic devices, basic electronics for illumination system, optical microscopy, actuators in the microscope, fundamentals of fluorescence microscopy, and advanced imaging techniques. Prerequisites: ENGR 296 or ME 222 or consent of instructor.

**BME 485-3 Cellular and Molecular Biomechanics.** (Same as ME 485) Mechanics at the micron and nanoscale level relevant to living cells. Molecular forces, bond dynamics, force induced protein conformational changes. Structural basis of

living cells; contractile forces; mechanics of the biomembranes, the nucleus, the cytoskeletal filaments- actin, microtubule, intermediate filaments. Active and passive rheology techniques; microrheological properties of the cytoskeleton. Active cellular processes such as cell adhesion, cell spreading, control of cell shape, and cell migration. Discussion on the experimental techniques including single molecule approaches to understand these key cellular processes. Discussion on theoretical models that predict these cellular processes and their limitations. Introductory concepts of mechanobiology will be discussed. Prerequisites: ENGR 350A or 350B with a minimum grade of C or better; or graduate standing.

**BME 501-3 Statistics for Biomedical Engineers.** Theoretical introduction to the basic principles of statistical modeling and estimation focusing on biomedical engineering applications such as genetics and genetic-related disorders. Prerequisite: PHSL 410A or consent of instructor.

**BME 531-3 Biomedical Optical Diagnostic.** Theoretical and experimental principles of optically based diagnostic systems; emphasis on generating quantitative descriptions of biochemical and biophysical interactions of optic systems as applied to medical diagnostics and sensing. Spectroscopy is also covered. Restricted to graduate standing. Special approval needed from the instructor.

**BME 532-3 Introduction to Biomedical Imaging.** (Same as ECE 467 and ECE 567) Biomedical imaging. X-ray imaging. Computed tomography (CT). Ultrasound. Magnetic resonance imaging (MRI). Image quality. Image reconstruction. Prerequisite: MATH 305 with a grade of C or better or consent of instructor. Lab fee: \$30 to help defray cost of software licenses and equipment.

**BME 533-3 Speech Processing.** (Same as ECE 474, ECE 533) Fundamentals of speech production system, signal analysis of speech, speech coding, linear prediction analysis, speech synthesizing, and speech recognition algorithms. Prerequisite: MATH 305, or consent of instructor.

**BME 534-3 Biomedical Sensors & Measurements.** Design and evaluation of sensors with application in biomedical engineering. Instrumentation and Techniques for measurements related to biomedical applications. Prerequisite: PHSL 410A, CHEM 444, or consent of instructor.

**BME 535-3 Information Processing in Biomedical Engineering.** Methods for evaluating different approaches in signal processing systems for biomedical applications; provides familiarity with the variety of exciting software and hardware systems. Prerequisite: PHSL 410A, CHEM 444, or consent of instructor.

**BME 536-3 Biomedical Signal Modeling.** (Same as ECE 498, ECE 534) The nature of biomedical signals. Electricity in living tissue. Biomedical signal processing and modeling. Modeling and simulation of biomedical systems. Prerequisite: ECE 355 with a minimum grade of C. Restricted to enrollment in ECE program or consent of instructor.

**BME 537-3 Embedded Microprocessor System Design.** Design, analysis, and evaluation of microprocessor-based systems for biomedical implementation. Prerequisite: ECE 424 or consent of instructor.

**BME 538-3 Medical Instrumentation: Application and Design.** (Same as ECE 438 and ECE 538) This course introduces the students to the field of medical instrumentation. Medical

instrumentation is the application of advanced engineering technology to problems in biology and medicine. The course will focus on fundamentals of instrumentation systems, sensors, amplifiers, and signal precondition. In addition, the course also includes design and applications of medical instrumentation, biopotential measurement, biosensor, biomedical signal processing, and other related topics. Prerequisite: MATH 305 with a grade of C or better, or consent of instructor. Lab fee: \$45 to help defray cost of software licenses and equipment.

**BME 539-3 Biomechanics I.** Introduction to mechanical behavior of biological tissues and systems, influence of material properties on the structure and function of organisms, methods for the analysis of both rigid body and deformational mechanics with application to include biological tissues such as bone, muscle, and connective tissues. Prerequisite: ME 470 or consent of instructor.

**BME 540-3 Biomechanics II.** Advanced topics in biomechanics focusing on design, development and evaluation of artificial organs. Prerequisite: ME 470 or consent of instructor.

**BME 541-3 Diagnostic Ultrasound Physics.** (Same as ECE 494 and ECE 539) Diagnostic ultrasound is an ultrasound-based biomedical imaging technique used to visualize muscles, tissue, and many internal organs, to capture their size, structure and any pathological lesions. This course is an introduction to the principles and applications of biomedical ultrasound. This course will focus on fundamentals of acoustic theory, principles of ultrasonic detection and imaging, design and use of currently available tools for performance evaluation of diagnostic devices, and biological effects of ultrasound. Prerequisite: MATH 305 with a grade of C or better, or consent of instructor. Project-based fee: \$30 to help defray cost of software licenses and equipment.

**BME 542-3 Biomaterials.** This course addresses the bulk and surface properties of biomaterials used for medical applications. Artificial Organs and Tissues and Tissue Engineering are included. Analytical techniques pertinent to biomaterial evaluation, and testing. Prerequisite: ME 410 or consent of instructor.

**BME 577-3 Bioprocess Engineering.** (Same as ME 577) The course objective is to introduce bioprocessing concepts to ME and BME students. This will introduce the idea of designing a system to achieve a biological reaction objective. It will have content in pharmaceutical production, production of enzymes and other bioproducts, research involving cell culture reactors, pharmacokinetics and other bioprocessing. Special approval needed from the instructor.

**BME 592-3 to 6 Biomedical Capstone Design.** Individual advanced project, with heavy emphasis on design, selected by the student and approved by his advisor. The project must be strongly related to biomedical engineering. This project normally will be equivalent to three credit hours. However with the approval of the BME program coordinator, the project could be equivalent to a maximum of six credit hours. Special approval needed from the instructor.

**BME 593-1 to 3 Advanced Topics in Biomedical Engineering.** Lectures on advanced topics of special interest to students in various areas of biomedical engineering. This course number is used to test new experimental courses in Biomedical Engineering. Special approval needed from the instructor.

**BME 596-3 Introduction to Biomedical Engineering.** (Same

as ECE 596) Principles of biomechanics, biomaterials, electrophysiology, modeling, instrumentation, biosignal processing, medical imaging, and biomedical optics. Professional moral and ethical issues in biomedical research and development. Prerequisite: MATH 305, or consent of instructor.

**BME 597-1 Biomedical Research Ethics.** (Same as ECE 597) Series of lectures from distinguished speakers, from academia, industry and government, regarding ethical issues associated with biomedical research and development. Graded S/U or DEF only. Restricted to: enrollment in BME or ECE program.

**BME 598-2 (1,1) Biomedical Seminar.** Must be taken in two semesters, one credit hour per semester. The first hour must be taken during the student's first semester of study. The intent is to provide an introduction to biomedical engineering through a series of lectures from speakers, from academia, industry and government, regarding biomedical engineering. The second hour will be the traditional graduate seminar for the biomedical engineering program. Restricted to admission to BME program.

**BME 599-1 to 6 Thesis.** Students are eligible to register for thesis when they have completed Module 1 of the BME program and the approval of the instructor who will act as thesis advisor. Prerequisite: Completion of Module 1 coursework and consent of thesis advisor.

**BME 601-1 Continuing Enrollment.** For those graduate students who have not finished their degree programs and who are in the process of their thesis or capstone design course. The student must have completed all other course requirements to be eligible to register in this course. Concurrent enrollment in any other course is not permitted. Graded S/U or DEF only. Prerequisites: Completion of course work except BME 592 or 599.