

# Biomedical Engineering

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## Objectives of Biomedical Engineering Program

The principal objective of our undergraduate program is to prepare students for productive careers in the field of biomedical engineering. As a department in New Jersey's technological research university, we anticipate that a significant number of our graduates will serve in the medical device and biotech industries in the state. But we also anticipate that many of our graduates will utilize their preparation in biomedical engineering to enter into other related fields such as medicine, dentistry, law, business or management. We expect our graduates to demonstrate effective leadership and to be prepared to work in culturally diverse environments. We also expect them to be able to use their multidisciplinary background to foster communication across professional and disciplinary boundaries and to remain mindful of the ethical and social implication of their work. We expect them to be able to integrate their fundamental knowledge in the basic sciences, mathematics, and engineering to address and solve a wide range of problems in medicine and biology. In keeping with the complex and continuously evolving nature of the field of biomedical engineering, we expect that most of our graduates will continue their formal education in advanced programs and that our alumni will engage in life-long learning.

## Description of Biomedical Engineering Programs

Biomedical engineering students combine a study of fundamental physiological and biological fundamental processes with a study of engineering methods. Within the biomedical engineering program, there are a number of focus areas, which lead to specific program tracks for undergraduate study. The bioinstrumentation track utilizes electrical engineering methods extensively. The biomechanics track brings mechanics and mechanical engineering methods into play. The biomaterials and tissue engineering track employs tools from chemical engineering and materials science.

For students committed to pursuing a professional career in an area other than engineering, the Engineering Science Accelerated Programs for Pre-Health and Pre-Law offer challenging educational opportunities. These programs involve a concentration in Biomedical Engineering while also meeting the broad requirements for the degree of Bachelor of Science in Engineering Science. These non-accelerated programs have attenuated engineering course requirements and are designed to prepare the student upon graduation to pursue advanced education in a professional school in medicine, dentistry, optometry, physical therapy or law.

The program requires only three years of attendance at NJIT with subsequent completion of the program via courses taken during the first year of professional school. Examples of research activity within the biomedical engineering field include signal processing of electrocardiograms, electroencephalograms, electromyograms; design of clinical instrumentation (e.g., for ophthalmology); design and analysis of prosthetic devices such as knees, hips and heart valves; design of robotic techniques for rehabilitation; experimental testing of the control of eye movements and other skeletal motor control systems; gait and limb motion analysis; development of new biomaterials (including many containing living cells) for both hard tissues (bone and teeth) and soft tissues (muscle, skin, cartilage, blood vessels), biomechanical testing of myocardial and vascular tissue; modeling and simulation of cardiac and vascular dynamics; modeling and simulation of the function of other organs such as lungs and kidneys; clinical image processing; biomedical applications of MEMS (micro electro-mechanical systems). Research is conducted cooperatively between NJIT and neighboring medical institutions.

## Mission of Biomedical Engineering

1. Educate undergraduate students for productive careers and life-long learning, especially in the health-related areas of industry, the professions, and government service
2. Educate biomedical engineering graduate students for employment in industry, health professions, government, or academe
3. Emphasize preparation for leadership roles for all levels of students, both undergraduate and graduate
4. Engage in research to support the advanced education of graduate students, maintain the intellectual vitality of the faculty, and expand the frontiers of knowledge in areas of importance to the state and the nation
5. Publish and present the results of our intellectual activities, resulted from both research and teaching advances
6. Serve our profession through membership and leadership in national and international societies
7. Serve our wider constituencies by offering our expertise to other health-related professionals, industries, and state and local communities

## Program Educational Objectives

1. To prepare students for productive careers related broadly to biomedical engineering. It is anticipated that BME graduates will embark upon diverse career paths, serve the medical device/pharmaceutical/biotechnology industries, and use their education in a variety of related endeavors including medicine, dentistry, law, business, government, and other engineering/scientific fields.
2. While working within their selected career path, we expect that our alumni will demonstrate the following traits:
  - a. **BME alumni are integrators:** We expect BME graduates to successfully and effectively integrate their fundamental knowledge of sciences, mathematics, liberal arts, and engineering analysis into actions that address and solve a wide range of problems, especially those related to medicine and biology.
  - b. **BME alumni continue their professional growth:** We expect BME graduates to advance their skills through professional growth and development opportunities provided by participation in a professional society, continuing education, or graduate study in engineering or other professional fields.

- c. **BME alumni are engaged in service:** We expect BME graduates to engage themselves in service to their chosen professional societies as well as their local, national, or global communities.

## Program Outcomes

By the time they graduate from the Biomedical Engineering Program, students will demonstrate that they possess the following knowledge and skill sets:

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to function on multi-disciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in life-long learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Similar to students outcomes Biomedical Engineering specific program criteria are incorporated throughout curriculum and linked to specific learning outcomes. Program-specific criteria:

- An understanding of biology and physiology
- The capability to apply advanced mathematics (including differential equations and statistics) to solve the problems at the interface of engineering and biology.
- The capability to apply advanced science and engineering to solve the problems at the interface of engineering and biology.
- The ability to make measurements on and interpret data from living systems.
- Addressing the problems associated with the interaction between living and non-living materials and systems.

The program is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012 - telephone (410)347-7700 <http://abet.org>.

## NJIT Faculty

### A

Adamovich, Sergei, Associate Professor

Alvarez, Tara L., Professor

Arinzeh, Treena L., Professor

### B

Biswal, Bharat, Professor

### C

Chandra, Namas, Professor

Chaudhry, Hans, Research Professor

Cho, Cheul, Assistant Research Professor

### D

Di, Xin, Assistant Research Professor

### F

Foulds, Richard A., Associate Professor

**G**

Georges Deveau, Penelope, University Lecturer

**H**

Haorah, James, Associate Professor

Hunter, William C., Professor

**I**

Ihlefeld, Antje, Assistant Professor

**J**

Jaffe, Michael, Research Professor

Jiang, Zhiguo, Research Professor

**L**

Lee, Eun Jung, Assistant Professor

Li, Xiaobo, Associate Professor

**M**

Mantilla, Bruno Antonio, University Lecturer

**O**

Ophir, Zohar, Research Professor

**P**

Perez-Castillejos, Raquel, Assistant Professor

Peringady, M. A. Muneer, Assistant Research Professor

Pfister, Bryan J., Chair

**R**

Reisman, Stanley, Professor Emeritus

**S**

Sahin, Mesut, Professor

Schesser, Joel, Senior University Lecturer

Skotak, Maciej, Assistant Research Professor

**V**

Van Buskirk, William C., Distinguished Professor Emeritus

**Programs**

- Biomedical Engineering - B.S. (<http://catalog.njit.edu/undergraduate/newark-college-engineering/biomedical/bs>)

**Accelerated Programs** (<http://catalog.njit.edu/undergraduate/academic-policies-procedures/special-degree-options>)

- Biomedical Engineering, Pre-Health - Accelerated B.S. (<http://catalog.njit.edu/undergraduate/newark-college-engineering/biomedical/accelerated-bs-prehealth>)

Biomedical Engineering Minor (<http://catalog.njit.edu/undergraduate/newark-college-engineering/biomedical/minor>) (for Engineering Science students)

Nanotechnology Minor (<http://catalog.njit.edu/undergraduate/newark-college-engineering/biomedical/nanotechnology-minor>)

## Biomedical Engineering Courses

### **BME 101. Introduction to Biomedical Engineering. 0 credits, 3 contact hours (3;0;0).**

This course is open only to freshmen and new transfer students. Faculty members describe their research in biomedical engineering.

### **BME 102. Biomedical Engr Research. 1 credit, 1 contact hour (1;0;0).**

Corequisite: FED 101 OR BME 111 Students at our prehealth program aim to be in medical practice. This course offers them to critically read medical engineering articles, understand it, research it and present engineering design principles to our faculty. This will enhance their ability to both succeed professionally and to contextualize their chosen vocations.

### **BME 105. Introduction to Human Physiology I. 2 credits, 2 contact hours (2;0;0).**

### **BME 106. Introduction to Human Physiology II. 1 credit, 1 contact hour (1;0;0).**

### **BME 111. Introduction to Physiology. 3 credits, 3 contact hours (3;0;0).**

This course is open only to freshmen and transfer students. An overview of human physiology is presented as an introduction to subsequent core courses in the Biomedical Engineering curriculum. Not intended to be an exhaustive review of physiology, the course will instead emphasize key examples that highlight understanding of the interaction between the biomedical and engineering worlds.

### **BME 301. Electrical Fundamentals of Biomedical Engineering. 3 credits, 4 contact hours (1;3;0).**

Prerequisites: Grade of C or higher in PHYS 121 and MATH 112. Course lectures and laboratories will address important issues for biomedical engineers at the introductory level; covering the origins of bio-electric signals and the instrumentation involved in collection of biopotentials from the electrodes to processing of the signals on the computer. Some other topics included are the transducers/sensors and modern engineering software used in bio-instrumentation. Laboratory work will provide hands-on experience in all of these areas. The course will also address practical issues in design of medical devices such as noise, resolution, linearity, and saturation. This course is offered in Studio format that involves the integration of lectures and labs into one highly participatory structure.

### **BME 302. Mechanical Fundamentals of Biomedical Engineering. 3 credits, 4 contact hours (1;3;0).**

Prerequisites: Grade of C or higher in PHYS 121 and MATH 112. BME 301 is not a prerequisite. The format is identical to that of BME 301. Course lectures and laboratories will address important issues covering the mechanical fundamentals that are important bases for later learning experiences. This course introduces the students to engineering mechanics and how those principles are relevant to biomechanical issues. This course is offered in Studio format that involves the integration of lectures and labs into one highly participatory structure.

### **BME 303. Biological and Chemical Foundations of Biomedical Engineering. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: Grade of C or higher in (CHEM 126 or CHEM 122) and PHYS 121. This course covers organic chemistry, biochemistry and cellular mechanics in sufficient depth to give biomedical engineering students a strong enough background for them to understand the introductory aspects of the discipline, which focus on the application of engineering principles to medicine and surgery.

### **BME 304. Material fundamentals of Biomedical Engineering. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: A Grade of C or higher in (CHEM 126 or CHEM 122) and BME 111. This course is an introduction to the field of biomaterials with an emphasis on the wound healing process and interactions between the human body and implanted devices fabricated from various types of biomaterials. The thrust of this course will be to illuminate the processes occurring at the tissue-biomaterial interface. Attention will be given to the biological events occurring at the molecular level on the surface of an implanted device. The nature of these surfaces and the physiological consequences of these processes will be examined in terms of how the body and functioning of the device are impacted.

### **BME 310. Biomedical Computing. 3 credits, 4 contact hours (3;1;0).**

Prerequisite: Grade of C or higher in BME 111 and BME 301 and CS 101. This course covers the application of digital signal processing to biomedical problems. Application of programming language common in engineering, for signal acquisition and processing. Applications include analysis of the electrocardiogram and other electrical signals generated by the body.

### **BME 311. Co-op Work Experience. 3 credits, 3 contact hours (0;0;3).**

Restriction: sophomore standing or above, approval of department, and permission of Career Development Services. Students gain major-related work experience and reinforcement of their academic program. Work assignments facilitated by the co-op office and approved by the department. Mandatory participation in seminars and completion of a report. Note: Normal grading applies to this COOP Experience.

### **BME 321. Adv Mechanics for Biomed Engr. 3 credits, 3 contact hours (3;0;0).**

Prerequisite: BME 302 with a grade of C or better This course provides an understanding of engineering mechanics, especially as applied to biomechanical systems. Students should be familiar with static equilibrium analysis and concepts of stress and strain. Course topics include method of sections, area moment of inertia, mechanical properties of materials, torsion, bending, stress transformation, Mohr's circle, and deflection of beams.

### **BME 333. Biomedical Signals and Systems. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 310 and MATH 222. BME Tools such as the Laplace and Fourier Transforms, time-frequency analysis are introduced. Applications include signals and noise, processing of the ECG, mathematics of imaging and derivation of useful physiological parameters from input signals.

### **BME 351. Introduction to Biofluid Mechanics. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 111, BME 302, MECH 236 and MECH 320 all with a C or better. Introduction to the principles of fluid flow. Basic fluid principles, such as fluid properties, fluid statics, conservation of mass, momentum, and energy will be discussed and presented in BME context. Special attention will be given to the non-Newtonian nature of blood, viscous flow in arteries, unsteady flows, and to the fluidic output of the heart. The textbook material will be supplemented throughout the course to emphasize examples relative to BME.

**BME 372. Biomedical Electronics. 3 credits, 3 contact hours (3;0;0).**

Prerequisite: BME 111 and BME 301 with a C or better. The first of a two-semester sequence that covers the design of electronic circuits for Biomedical applications. This course covers basic operational amplifier circuits as well as the operation of semiconductor diodes and transistors. An introduction to digital logic circuits is also provided. Computer simulation as well as hands-on breadboarding of electronic circuits are used throughout the course to supplement the lectures.

**BME 373. Biomedical Electronics II. 3 credits, 3 contact hours (3;0;0).**

Prerequisite: BME 372. This is a continuation of BME 372 emphasizing biomedical applications of oscillators, active filters, and wave-shaping circuits.

**BME 382. Engineering Models of Physiological Systems. 3 credits, 5 contact hours (5;0;0).**

Prerequisites: BME 111, BME 301, BME 302 and Math 222 all with a C or better. Students learn to develop quantitative models of organs and organ systems from an engineering viewpoint. Students translate their understanding of physiological systems into models that evolve dynamically based on engineering block diagrams. Additional topics include: hierarchical structure, sensitivity analysis, parameter estimation, negative feedback control, and characteristic traits of models. Students will use models to gain insight into how a physiological system functions and to design a biomedical engineering device or procedure that interacts with the physiological system. Systems studied include the cardiovascular system, gas exchange in the lungs, nerve and muscle action potentials, and musculo-skeletal spinal reflex.

**BME 383. Measurement Lab for Physiological Systems and Tissue. 3 credits, 4 contact hours (1;3;0).**

Prerequisites: BME 302, BME 310, and (MATH 279 or MATH 333). Through laboratory experiences, students will apply engineering methods for measuring and interpreting the properties of physiological systems and biological tissues. Topics include measurements relevant to cardio-pulmonary, nerve and muscular systems.

**BME 384. Biomechanics Laboratory. 3 credits, 4 contact hours (1;3;0).**

Prerequisites: BME 111, BME 302, MECH 236, MECH 320, CS 101 and MATH 279 all with a C or better. This course is an introduction to the experimental analysis of the biomechanics of human motion. Laboratory experiments include the application and integration of anatomical and mechanical concepts to a wide variety of activities. Students will develop basic competence in a systematic approach to the observation, analysis and evaluation of human movement in clinical, educational, and industrial environments.

**BME 385. Cell and Biomaterial Engineering Laboratory. 3 credits, 4 contact hours (1;3;0).**

Prerequisite: MATH 112, PHYS 121 BME 304 and (MATH 279 or MATH 333) all with a C or better. This laboratory course is designed to provide students with valuable hands-on experience in the field of cellular and biomaterial engineering. Experiments include biomaterial fabrication and characterization, mechanical testing of biomaterials, colorimetric protein assay, cell-based assay, the basics of cell culture techniques, the basics of light and electron microscopy, and image capture and analysis. A lecture on the principles of a given technique will be followed by laboratory activity.

**BME 386. Bioinstrumentation Laboratory. 3 credits, 4 contact hours (1;3;0).**

Prerequisites: ECE 251, BME 372 and (MATH 279 or MATH 333). Laboratory exercises involve projects at all levels of a bioinstrumentation system from sensors to data acquisition and data processing. Analog and digital circuits are constructed to condition the signals from sensors and convert them into a format that can be displayed or acquired into a computer. The final projects help to develop the skills to integrate various parts of a bioinstrumentation system, collect and analyze data and troubleshoot a circuit.

**BME 411. Co-op Work Experience. 0 credits, 0 contact hours (0;0;0).**

Prerequisites: BME 311 and completion of sophomore year, approval of department, and permission of Career Development Services. Students gain major-related work experience and reinforcement of their academic program. Work assignments facilitated by the co-op office and approved by the department. Mandatory participation in seminars and completion of a report. May count as BME or approved elective. Grade will now be issued as a letter grade.

**BME 420. Advanced Biomaterials Science. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 302, BME 304, MATH 222 and MTSE 301. The goal of this course is to understand material selection, important properties of materials for use in the body and failure modes of applied biomaterials. The course will cover the structure and properties of materials used as biomaterials including metals, ceramics, synthetic polymers, and biopolymers. The structure of these materials will be explored to understand how it defines the behavior of a material. The bulk behavior of materials will be reviewed, including the generalized Hooke's Law, and new concepts will be introduced (including thermal strain, surface properties, and viscoelasticity). Students will be presented with problems of property characterization, failure analysis and performance testing. Students will work in teams to analyze a marketed implant or device using biomaterial(s) using the tool and concepts learned in the course.

**BME 422. Biomaterials Characterization. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: Math 112, Phys 121, BME 304 and MTSE 301 all with a C or better. The quantum mechanical origins of spectroscopy, the relationship of spectroscopic behavior to thermal characteristics of a material, and the differences in approach to the chemical and physical characterization of synthetic and biological polymers are discussed.

**BME 427. Biotransport. 3 credits, 3 contact hours (3;0;0).**

Prerequisite: MATH 222, (BME 303 or R120 102), and CHE 230. This course provided an introduction to basic concepts in thermodynamics and transport phenomena as applied to biological systems. The structure and composition of the body will be covered followed by an exploration of the properties of the blood and its flow in the cardiovascular system, and the body as a heat source and as a series of compartments involved in the mass transfer of materials (such as those in the kidneys and lungs). Design of artificial kidneys and heart-lung machines is also explored.

**BME 430. Fundamentals of Tissue Engineering. 3 credits, 3 contact hours (3;0;0).**

Prerequisite: BME 302, (BME 303 or R120 102), BME 304, MATH 222 and MTSE 301. This course is an introduction to the field of tissue engineering as a therapeutic approach to treating damaged or diseased tissues in the biotechnology industry. In essence, new and functional living tissue can be fabricated by delivering cells, scaffolds, DNA, proteins, and/or protein fragments at surgery. This course will cover the advances in the fields of cell biology, molecular biology, material science and their relationship towards developing novel "tissue engineered" therapies.

**BME 451. Biomechanics I. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 302, MECH 236 and MECH 320. Tensor analysis. Kinematics of continuous media. Stress. The elastic solid. Newtonian fluid. Conservation principles of mass, momentum and energy. Viscometric flows. Formulation of constitutive equations. Applications to the modeling of bone and other living tissues.

**BME 452. Mechanical Behavior and Performance of Biomaterials. 3 credits, 3 contact hours (3;0;0).**

Prerequisite: BME 302, BME 304, MATH 222, MATH 337, MATH 279, and MECH 320. Biomaterial selection and performance is essential to the design and implementation of most any biomedical application. Students will learn about important properties of materials for use in the body and failure modes of applied biomaterials. Material behavior will be reviewed, including the generalized Hooke's Law, and new concepts will be introduced including thermal strain, surface properties, and viscoelasticity. Material biocompatibility will be introduced in regards to body responses including cell and tissue interaction, toxicity and safety.

**BME 471. Principles of Medical Imaging. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 301 and BME 310 This is an introductory undergraduate course in biomedical imaging. This course will cover medical physics, instrumentation, data acquisition and processing to generate structural and functional images. A number of modalities including X-ray, Computer Tomography, Ultrasound, and magnetic resonance imaging systems are included. This course is an elective in the Bioinstrumentation track.

**BME 478. Introduction to CAD for Biomechanics. 3 credits, 4 contact hours (2;2;0).**

Prerequisites: BME 302 and MECH 320. Introduction to Computer Aided Designing and analysis as applied to biomedical engineering design programs. Topics include theoretical insight into the process of design and geometrical modeling and design using industry standard CAD (Computer Aided Design) software packages. The course will also include several projects involving the application of design principles to standard problems in biomedical design.

**BME 479. BioMicroElectroMechanical Systems. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 301, BME 302, and BME 304. This course focuses on the study of the broad body of knowledge required to design, fabricate, and test BioMEMS. We define BioMEMS as any type of biomedical devices for the fabrication of which miniaturization techniques (at least in part) are required. BioMEMS are used in advanced analytical techniques (microfluidic devices), implantable chips, biomedical sensors and actuators, and in-vitro tissue modeling. BioMEMS for diagnosis as well as for cell biology and tissue engineering are studied. This course provides a hands-on approach to BioMEMS and microfluidic devices and allows students to design, fabricate, and characterize their own BioMEMS.

**BME 489. Medical Instrumentation. 3 credits, 3 contact hours (3;0;0).**

Prerequisites: BME 372, BME 310. This course covers the hardware and instrumentation needed to measure variables from different physiological systems. The following topics will be taught: electrodes, sensors and transducers. Bioelectric amplifiers, electrical safety and computing. Applications include the study and design of instrumentation for measurement of the ECG, EEG, EMG, respiratory system, nervous system in general.

**BME 491. Research and Independent Study I. 3 credits, 3 contact hours (0;0;3).**

In depth research experience taught under the guidance of a professor typically within a laboratory. Approved requirements are needed for engineering credit. Research thesis required. Needs permission of professor.

**BME 492. Research and Independent Study II. 3 credits, 3 contact hours (0;0;3).**

Prerequisite: BME 491. Approved requirements are needed for engineering credit. Research thesis required. Needs permission of professor.

**BME 493. Honors Research Thesis I. 3 credits, 3 contact hours (0;0;3).**

Prerequisites: GPA 3.5, an appropriate research methods course and ENG 352 Part of a two semester undergraduate research thesis. Students will learn how to formulate a hypothesis, design a scientific based experiment, analyze data using statistics, interpret data, and describe work within oral defense and written thesis.

**BME 494. Honors Research Thesis II. 3 credits, 3 contact hours (0;0;3).**

Prerequisites: BME 393 Part of a two semester undergraduate research thesis. Students will learn how to formulate a hypothesis, design a scientific based experiment, analyze data using statistics, interpret data, and describe work within oral defense and written thesis.

**BME 495. Capstone Design I. 3 credits, 4 contact hours (1;3;0).**

Restriction: Senior standing. Prerequisite: BME 372 or MTSE 301 or (MECH 236 and MECH 320). The goal of this course is to provide students with the guidance to choose a capstone design topic and advisor conduct library/search engine background research and to prepare the design proposal for their chosen project. The course introduces the student to the definition of design as well as introducing issues of intellectual property, bioethics and safety, and professional societies.

**BME 496. Capstone Design 2. 3 credits, 4 contact hours (1;3;0).**

Prerequisite: BME 495. Implementation of the project approved in BME 495. This portion of the project includes library research, time and cost planning, oral and written reports, as well as construction, troubleshooting and demonstration of a working prototype.

**BME 498. ST.: 3 credits, 3 contact hours (3;0;0).**