

# DEPARTMENT OF BIOMEDICAL ENGINEERING

## Introduction

The joint Department of Biomedical Engineering (BME) is a department of both the University of North Carolina at Chapel Hill (UNC–Chapel Hill) and North Carolina State University (NC State). The department oversees a joint graduate and undergraduate program at these institutions. While a complete curriculum is offered on the UNC–Chapel Hill campus, students can elect to take any number of classes at NC State. The joint program also leverages the industry resources in Research Triangle Park, located roughly half way between the two campuses, providing unique opportunities for students.

Biomedical engineering is a profession that develops and applies engineering knowledge and experience to solve problems in biology and medicine and to enhance health care. Biomedical engineers are professionally trained to combine the rigors of medical and biological studies with the power of engineering analysis and design. People become biomedical engineers to be of service to others, to enjoy the excitement of understanding living systems, and to use state-of-the-art science and technology to solve the complex problems of medical care. The emphasis in biomedical engineering is on finding solutions by researching, testing, and applying medical, biological, chemical, electrical, and materials engineering approaches. Biomedical engineers are unique individuals who make contributions to health care that are both satisfying to themselves and beneficial to others.

## Facilities

The Department of Biomedical Engineering houses undergraduate teaching laboratories in Phillips Hall and design laboratories in Mary Ellen Jones. These laboratories house a variety of mechanical and electronic fabrication tools as well as laboratories dedicated to cell culture and microbiology. The BeAM Makerspace facilities are available to all UNC students, and these facilities house a variety of mechanical and electronic fabrication tools. More information is available at the UNC BeAM website (<https://beam.unc.edu/>).

## Graduate School and Career Opportunities

Many students from this program have pursued further education in graduate school in biomedical engineering. Our alumni have attended many of the top-ranked biomedical engineering programs. In addition, some students have pursued graduate degrees in other disciplines in engineering, as well as related fields such as microbiology, sports physiology, public health, and business/engineering management, among others. Students have also been accepted into clinical programs such as medical, dental, physical therapy, and pharmacy schools (in many cases, the student must take several additional courses to meet the requirements for clinical programs).

For those interested in going directly into a career, biomedical engineering is one of the fastest growing career opportunities. Graduates are employed by hospitals, pharmaceutical companies, medical device and testing companies, government agencies, universities, and medical schools.

### Major

- Biomedical Engineering Major, B.S. (<https://catalog.unc.edu/undergraduate/programs-study/biomedical-engineering-major-bs/>)

### Graduate Programs

- M.S. in Biomedical Engineering (<https://catalog.unc.edu/graduate/schools-departments/biomedical-engineering/>)
- Ph.D. in Biomedical Engineering (<https://catalog.unc.edu/graduate/schools-departments/biomedical-engineering/>)

## Professors

Lianne Cartee, Ke Cheng, Paul Dayton, M. Gregory Forest, Caterina Gallippi, Shawn Gomez, Edward Grant, Helen Huang, Leaf Huang, Michael Jay, Weili Lin, H. Troy Nagle, Roger Narayan, J. Michael Ramsey, Koji Sode, George Stouffer.

## Associate Professors

Ashley Brown, Jacqueline Cole, Michael Daniele, Bob Dennis, Kenneth Donnelly, Oleg Favorov, Matthew Fisher, Jason Franz, Donald Freytes, Michael Gamcsik, David Hill, Xiaogang Hu, Devin Hubbard, Naji Husseini, Derek Kamper, David Lalush, Jeffrey Macdonald, Scott Magness, Gianmarco Pinton, Nitin Sharma, Mark Tommerdahl, Anka Veleva, Bruce Wiggin, David Zaharoff.

## Assistant Professors

Amy Adkins, Pritha Agarwalla, Wen Yih Aw, Rahima Benhabbour, Yevgeny Brudno, Joseph Burclaff, Melissa Caughey, Silvia Ceballos, Brian Diekman, Alon Greenbaum, Kennita Johnson, Jinwood Kim, Wesley Legant, Ming Liu, Virginia Papadopoulou, Ross Petrella, William Polacheck, Imran Rizvi, Michael Sano, Francisco Santibanez, James Tsuruta.


## Professors Emeriti

Frank Abrams, Albert Banas, Carol Lucas.

## Professor of the Practice

Matthew Penny.

## BMME–Biomedical Engineering Undergraduate-level Courses

 **BMME 89. First Year Seminar: Special Topics. 3 Credits.** Special topics course. Content will vary each semester.

### Rules & Requirements

 **IDEAs in Action Gen Ed: FY-SEMINAR.**

**Grading Status:** Letter grade.

**BMME 150. Introduction to Materials Science. 3 Credits.**

Focus on the materials science and processing of electronic, metallic, polymeric, ceramic, and composite materials. The electronic, optical, magnetic, and structural properties of materials are related to their applications. Majors only.

### Rules & Requirements

**Requisites:** Prerequisites, CHEM 102; co-requisites, MATH 383 and PHYS 117 or 119.

**Grading Status:** Letter grade.

**BMME 160. Statics. 3 Credits.**

Course restricted to admitted majors only. Course covers rigid body mechanics of bodies at equilibrium or at rest (statics), and an introduction to rigid body mechanics of bodies in motion (dynamics). A foundation in engineering concepts and practices required to design and analyze many types of structural members is presented. Provides a foundation for more advanced courses.

**Rules & Requirements**

**Requisites:** Prerequisites, MATH 232, and PHYS 116 or 118.

**Grading Status:** Letter grade.

**BMME 190. Special Topics in Biomedical Engineering. 1-3 Credits.**

A study in the special fields under the direction of the faculty. Offered as needed for presenting material not normally available in regular BMME courses. Honors version available.

**Rules & Requirements**

**Repeat Rules:** May be repeated for credit; may be repeated in the same term for different topics; 9 total credits. 3 total completions.

**Grading Status:** Letter grade.

**BMME 201. Computer Methods in Biomedical Engineering. 3 Credits.**

This course introduces students to problem-solving techniques using the MATLAB programming language. Fundamental computer science basics are taught as they relate to problems encountered in biomedical engineering and other scientific disciplines. Programming activities will incorporate actual data (e.g., stress/strain data and microscopy images) for relevant, real-world examples. Course restricted to admitted majors only.

**Rules & Requirements**

**Grading Status:** Letter grade.

**BMME 205. Biomedical Mechanics. 4 Credits.**

Study of the state of rest or motion of bodies subjected to the action of forces. Properties of force systems, free body diagrams, concepts of equilibrium, kinematics of particles, Newton's laws, conservational principles of energy of momentum in mechanics, mechanical vibrations, and their applications in biomedical systems. Biomedical Engineering majors only.

**Rules & Requirements**

**Grading Status:** Letter grade.

**BMME 207. Biomedical Electronics. 4 Credits.**

Fundamentals of analog and digital circuit analysis and design as applied to biomedical instrumentation and measurement of biological potentials. Passive circuit components, node and mesh analysis, transient behavior, operational amplifiers, frequency response, analog filter design, diode, transistors, biological signal acquisition, binary math and logical operators, digital circuit design, circuit simulation tools and techniques. Laboratory exercises supplement the topics presented in class lectures. Previously offered as BMME 350. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisite, PHYS 117 or 119.

**Grading Status:** Letter grade.

**BMME 209. Materials Science of Biomaterials. 4 Credits.**

Focus on the materials science and processing of electronic, metallic, polymeric, ceramic, and composite materials. The electronic, optical, magnetic, and structural properties of materials are related to their applications. Lab component focused on integrating biological engineering and materials engineering principles by exploring key topics in materials science. Topics include biomaterial fabrication, evaluation of their physical properties and interpretation of results. Majors only.

**Rules & Requirements**

**Requisites:** Pre- or Corequisite, PHYS 117 or 119.

**Grading Status:** Letter grade.

**BMME 215L. Biomedical Mechanics Lab. 1 Credits.**

Statics and dynamics subjects will be studied with experimental techniques, including strain gauges and accelerometers, and computational methods, including finite-element analysis and motion capture.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 160.

**Grading Status:** Letter grade.

**BMME 217L. Biomedical Electronics Laboratory. 1 Credits.**

This laboratory course is a corequisite to BMME 207 and complements it with relevant labs and examples. Laboratory in analog and digital circuit analysis. Electrical safety, exercises in resistor networks, capacitors and inductors, steady-state and dynamic circuit behavior, active circuits, amplifiers, logic gates, combinatorial and sequential circuits, elementary digital system design, A/D conversion, and biomedical applications. Biomedical and health sciences engineering majors only.

**Rules & Requirements**

**Requisites:** Prerequisite, PHYS 117 or 119.

**Grading Status:** Letter grade.


**BMME 219L. Materials Science of Biomaterials Lab. 1 Credits.**

Introductory laboratory experience focused on integrating biological engineering and materials engineering principles by exploring key topics in materials science. Topics include biomaterial fabrication, evaluation of their physical properties and interpretation of results.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 150.

**Grading Status:** Letter grade.

** BMME 295. Research in Biomedical Engineering for Undergraduates. 1-3 Credits.**

Permission of the director of undergraduate studies. At least three hours per credit hour of independent work a week. Research with a faculty mentor. Approved learning contract required. Research proposal and final research paper also required. Previously offered as BMME 395.

**Rules & Requirements**

** IDEAs in Action Gen Ed:** RESEARCH.

**Making Connections Gen Ed:** EE- Mentored Research.

**Grading Status:** Letter grade.

**BMME 298. Biomedical Engineering Design and Manufacturing I. 2 Credits.**

This is the first in a series of four courses in biomedical design. The course introduces the tools and problem-solving skills required in the field of biomedical engineering. Majors only.

**Rules & Requirements**

**Grading Status:** Letter grade.

**BMME 301. Human Physiology : Electrical Analysis. 4 Credits.**

This course includes an electrical analysis approach to human physiology from the biomedical engineering perspective with an emphasis on neural, sensory, and cardiac physiology. Autonomic and somatic motor control will be discussed. Engineering applications, including neural stimulator, functional imaging, cochlear implants, artificial noses, vestibular implants, visual implants, artificial larynges, pacemakers and defibrillators will be discussed. Assignments include computer-based exercises using MATLAB. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisite, BIOL 101L, (BMME 207 or BMME 350), (BMME 201 or COMP 116).

**Grading Status:** Letter grade.

**BMME 302. Human Physiology: Mechanical Analysis. 4 Credits.**

Explores a quantitative approach to human physiology from the biomedical engineering perspective with an emphasis on systems physiology described using mechanical properties. Topics include the physiological and mechanical behavior of the blood vessels, lungs, kidney, and muscles. In lab exercises, students investigate mechanical properties of fluids, electrolyte exchange in dialysis, spirometry, and blood pressure measurement among other topics. Culminates with the design of a novel laboratory experiment.

**Rules & Requirements**

**Requisites:** Prerequisites, BIOL 101, BMME 160 or BMME 205, and BMME 150 or BMME 209.

**Grading Status:** Letter grade.

**BMME 315. Biotransport. 3 Credits.**

This course serves as introduction for engineers pursuing transport phenomena and for future pharmaco-engineers requiring predictive models of mass transfer or pharmacodynamic models. Material is designed to address heat and mass transfer issues in nanotechnology, microfabrication, mems, cell therapies, bioartificial organs, as well as pharmacodynamic modeling of dynamic "omics" datasets. Previously offered as BMME 475. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 201, or COMP 116, and MATH 383.

**Grading Status:** Letter grade.

**BMME 325. Biochemistry for Biomedical Engineers. 3 Credits.**

An overview of how alterations in bioenergetics, enzyme catalysis, protein and membrane structure, carbohydrate, lipid and nucleic acid metabolism affect human health. Topics include: biological thermodynamics, energy of macromolecular structure and binding, structure/function of proteins, enzymes and nucleic acids, kinetics, enzyme catalysis and biochemical network analysis, generation of chemical and electrical potential in membranes, carbohydrate/lipid/protein metabolism and energy production, DNA synthesis, transcription, and the technologies used to monitor/detect biochemical processes.

**Rules & Requirements**

**Requisites:** Prerequisites, CHEM 261, and BMME 150, or BMME 209.

**Grading Status:** Letter grade.

**BMME 335. Biomaterials. 3 Credits.**

Focus on the mechanical, chemical, and biocompatibility considerations of any material (e.g., metal, ceramic, or polymer) designed to interface with the body. Various applications of biomaterials are presented and analyzed, including femoral implants and vascular grafts, in order to guide students in a semester-long design project. Previously offered as BMME 510. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisites, BIOL 101 and BMME 209 or BMME 150.

**Grading Status:** Letter grade.

**BMME 345. Biomedical Solid Mechanics. 3 Credits.**

This course covers topics ranging from multi-body systems to stress superposition to failure criteria to prepare students for the more advanced subjects of biomechanics and rehabilitation engineering. Topics include free-body diagrams, multibody statics and dynamics, linkage kinematics and kinetics, anthropometric kinematics, stress/strain/torsion, beam bending, stress superposition, constitutive relationship, strain gauges, finite-element analysis, failure analysis, and failure mechanisms. Restricted to Biomedical Engineering Majors.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 160, 205, or 215L, and BMME 150, 209 or 219L, and BMME 201 or COMP 116.

**Grading Status:** Letter grade.

**BMME 355. Biocontrols. 3 Credits.**

Quantitative analysis of dynamic and feedback control systems, including modeling of physiological systems and physiological control systems, system time and frequency responses, control characteristics, and stability analysis. Design techniques for feedback systems in biomedical applications. Majors only.

**Rules & Requirements**

**Requisites:** Pre- or corequisite, BMME 365.

**Grading Status:** Letter grade.

**BMME 365. Systems and Signals. 3 Credits.**

Analysis of linear systems by transform methods to networks, including Fourier transforms, Laplace transforms, and convolution. Survey of linear systems applications to biomedical problems. Previously offered as BMME 410. Majors only.

**Rules & Requirements**

**Requisites:** Pre- or corequisite, MATH 383.

**Grading Status:** Letter grade.

**BMME 375. Biomedical Microcontroller Applications. 3 Credits.**

Introduction to digital computers for real-time processing and control of signals and systems. Programming input and output devices using C and assembly language is stressed. Case studies are used to present software design strategies for real-time laboratory systems. Previously offered as BMME 580. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 201 or COMP 116; Pre- or corequisite, BMME 385.

**Grading Status:** Letter grade.

**BMME 385. Bioinstrumentation. 3 Credits.**

Fundamentals of biomedical instrument design and implementation. Topics include basic electronic circuit design, analysis of medical instrumentation circuits, analog-to-digital signal conversion, biosignal capture and storage, embedded microprocessors, system integration, and prototyping. This course is a lecture course with a project component. Previously offered as BMME 465. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 207 or BMME 217L, and BMME 201 or COMP 116.

**Grading Status:** Letter grade.

**BMME 386. Biomedical Instrumentation Design and Prototyping I. 1 Credits.**

Students will learn advanced topics in concept development, detailed design, fabrication, assembly, testing, deployment, and incorporation of user feedback in the design and fabrication of components and systems for research and technology development in biomedical engineering. Students will interact with faculty with many decades of research and commercial design experience to develop and deploy design solutions for BME laboratories and technology spin-outs. This course is the first in a series of two courses. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 385 and permission of instructor.

**Grading Status:** Letter grade.


**BMME 396. Independent Study in Biomedical Engineering. 1-3 Credits.**

Permission of the director of undergraduate studies. Independent study under a member of the biomedical engineering faculty. Approved learning contract required.

**Rules & Requirements**

**Repeat Rules:** May be repeated for credit. 12 total credits. 4 total completions.

**Grading Status:** Letter grade.

** BMME 398. Biomedical Engineering Design and Manufacturing II. 2 Credits.**

In this course, you will learn the validation and verification stages of the design process as applied to the development of new medical devices. This course is the second part of a 3 year sequence in which you will learn the process of biomedical engineering design along with technical skills that will allow you to develop new devices to solve unmet medical needs. Previously offered as BMME 310. Majors only. Honors version available.

**Rules & Requirements**

**IDEAs in Action Gen Ed:** FC-KNOWING.

**Requisites:** Prerequisite, BMME 298.

**Grading Status:** Letter grade.

**Advanced Undergraduate and Graduate-level Courses****BMME 405. Biomechanics of Movement. 3 Credits.**

This course provides an overview of musculoskeletal anatomy, and of the mechanical behavior of biological tissues and biological systems. Students learn to apply fundamental principles of mechanics to analyze movement in humans and other animals. Applications in rehabilitation and orthopedics are emphasized.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 160, or 205, and MATH 383.

**Grading Status:** Letter grade.

**BMME 420. Introduction to Synthetic Biology. 3 Credits.**

This course provides an introduction to the ideas and methodologies in the field of synthetic biology. Lectures focus on fundamental concepts in molecular biology and engineering as applied to biological system design. The laboratory portion of the course provides hands-on application of fundamental techniques in synthetic biology research. Majors only.

**Rules & Requirements**

**Requisites:** Pre- or corequisites, BMME 325 or CHEM 430; and BMME 335.

**Grading Status:** Letter grade.

**BMME 435. Biological Physics. 3 Credits.**

How diffusion, entropy, electrostatics, and hydrophobicity generate order and force in biology. Topics include DNA manipulation, intracellular transport, cell division, molecular motors, single molecule biophysics techniques, nerve impulses, neuroscience.

**Rules & Requirements**

**Requisites:** Prerequisites, PHYS 116 and 117, or PHYS 118 and 119.

**Grading Status:** Letter grade.

**Same as:** PHYS 405, BIOL 431.

**BMME 441. Thermal Physics. 3 Credits.**

Equilibrium statistical mechanics; the laws of thermodynamics, internal energy, enthalpy, entropy, thermodynamic potentials, Maxwell's relations.

**Rules & Requirements**

**Requisites:** Prerequisites, MATH 233, and PHYS 117 or 119; permission of the instructor for students lacking the prerequisites.

**Grading Status:** Letter grade.

**Same as:** PHYS 441.

**BMME 445. Systems Neuroscience. 3 Credits.**

Introduction to methodologies used to characterize a) the aggregate behavior of living neural networks and b) the changes in that behavior that occur as a function of stimulus properties, pharmacological manipulations, and other factors that dynamically modify the functional status of the network.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 351 or BMME 301 or BIOL 252.

**Grading Status:** Letter grade.

**BMME 447. Neural Basis of Rehabilitation Engineering. 3 Credits.**

The course will 1) introduce basic neuroscience topics underlying sensorimotor control, and 2) introduce different types of childhood and adult neuromuscular disorders with both central and peripheral origins. The main focus of the class will be on the different techniques used for diagnosis, assessment, and rehabilitation interventions.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 301 and BMME 345.

**Grading Status:** Letter grade.

**BMME 455. Biofluid Mechanics. 3 Credits.**

This course introduces students to basics of fluid mechanics (steady and pulsatile flows, laminar and turbulent flows, and Newtonian and non-Newtonian flows). Students learn the fundamental relationships and governing equations describing these types of flows and the basic physiology of certain systems that are highly associated with fluid flows.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 315 and one of BMME 205 or BMME 160.

**Grading Status:** Letter grade.

**BMME 461. Introduction to Medical Imaging. 3 Credits.**

This class covers the underlying concepts and instrumentation of modern medical imaging modalities. Review of applicable linear systems theory and relevant principles of physics. Modalities covered include X-ray radiography (conventional film-screen imaging and modern electronic imaging), computerized tomography (including the theory of reconstruction), magnetic resonance imaging, SPECT/PET, and ultrasound imaging.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 365.

**Grading Status:** Letter grade.

**BMME 470. Analysis of Tissue Engineering Technologies. 3 Credits.**

Lectures in this course address how to quantitatively evaluate functional engineered tissues. The course provides an overview of the field, with emphasis on detailed evaluation of scientific and commercial progress over time, and design principles that must be met to develop a process or fabricate a functional tissue-engineered part.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 335 or BMME 351, and BMME 302 or BIOL 252.

**Grading Status:** Letter grade.

**BMME 485. Biotechnology. 3 Credits.**

This course is designed to prepare a biomedical engineering student with the survey tools to understand key components in modern biotechnologies. Fundamental concepts, theory, design, operation, and analysis of the most common biotechnologies in bioengineering will be presented.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 325.

**Grading Status:** Letter grade.

**BMME 486. Biomedical Instrumentation Design and Prototyping II. 2 Credits.**

Students will build upon skills learned in BMME 386 and assume project leadership roles as well as team management roles for more complex projects involving design, fabrication, assembly, testing, deployment, and incorporation of user feedback in the design and fabrication of components and systems for research and technology development in biomedical engineering. Students will interact with highly experienced faculty to develop and deploy design solutions for BME laboratories and technology spin-outs.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 386 with a grade of A.

**Repeat Rules:** May be repeated for credit. 4 total credits. 2 total completions.

**Grading Status:** Letter grade.

**BMME 490. Special Topics in Biomedical Engineering. 1-9 Credits.**

A study in the special fields under the direction of the faculty. Offered as needed for presenting material not normally available in regular BMME courses. Majors only.

**Rules & Requirements**

**Repeat Rules:** May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 12 total completions.

**Grading Status:** Letter grade.

**BMME 495. Undergraduate Research in Biomedical Engineering as a Technical Elective. 3 Credits.**

Opportunity for hands-on faculty mentored research project in biomedical engineering. Approved plan of work required with significant independent research culminating in a final paper and presentation at an appropriate venue. Departmental approval required. Course may not be repeated. Permission of department.

**Rules & Requirements**

**IDEAs in Action Gen Ed:** RESEARCH.

**Grading Status:** Letter grade.

**BMME 505. Skeletal Biomechanics. 3 Credits.**

A firm understanding of the principles of mechanics is an important foundation to biomechanics. In this course, students will study the mechanics of materials with applications to the strength of bone, implant analysis, and testing of biological materials. A goal of this course is for students to understand how the interface of biology, mechanics, and therapies affect skeletal pathological conditions.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 160 and MATH 383.

**Grading Status:** Letter grade.

**BMME 511. Genetic Engineering. 3 Credits.**

The course introduces the engineering principles used to modify cells in a variety of biomedical applications. The format includes lectures, discussion of primary research literature, and application of engineering design principles through student projects. The goals are to 1) discuss genome editing technologies, 2) evaluate strategies for cellular reprogramming and directed differentiation of stem cells, and 3) illustrate how genetic modification can be harnessed for cellular therapy and research applications such as animal models.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 301 or BMME 302; and BMME 315 or BMME 325; recommended BMME 420 or BIOL 202.

**Grading Status:** Letter grade.



**BMME 523. Biomolecular Engineering. 3 Credits.**

This course introduces the use and creation of biomolecules for biomedical applications to foster the development of a mission oriented research plan to create engineered biomolecules for biomedical applications. Students will search, prepare, evaluate, design, and simulate biomolecules through lectures on the basic chemical and structural properties of biomolecules, exploiting varieties of biomolecules, practical methods to engineer biomolecules, and development of a student research plan. BME students only.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 325 or CHEM 430.

**Grading Status:** Letter grade.

**BMME 524. Biomolecular Sensing Technologies. 3 Credits.**

This course introduces the science and technology of biomolecular sensing technologies, the essence of biosensors, and biochemical and immunological in vitro/in vivo diagnostic devices. The focus of the class is biomolecules (enzymes, antibodies, binding proteins, receptors, aptamers, molecularly imprinted polymers, etc.), bioelectronics and biochemical principles employed in biosensor development. Majors only.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 325 or CHEM 430; recommended BMME 420 or BMME 511.

**Grading Status:** Letter grade.

**BMME 527. Targeted Photomedicine. 3 Credits.**

This course will introduce students to fundamental concepts and engineering approaches in targeted photomedicine, particularly for the treatment of cancer. Students will review and present research articles on emerging applications of photomedicine. The major deliverable will be an NIH-style research proposal, based on lecture material and a literature review, to help students gain an understanding of advancements in targeted photomedicine.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 325 or CHEM 430; and BMME 301 or 302.

**Grading Status:** Letter grade.

**BMME 550. Medical Imaging I: Ultrasonic, Optical, and Magnetic Resonance Systems. 3 Credits.**

Physical and mathematical foundations of ultrasonic, optical, and magnetic resonance imaging systems in application to medical diagnostics. Each imaging modality is examined, highlighting critical system characteristics: underlying physics of the imaging system, including mechanisms of data generation and acquisition; image creation; and relevant image processing methods, such as noise reduction.

**Rules & Requirements**

**Requisites:** Prerequisites, BIOS 550 and PHYS 128.

**Grading Status:** Letter grade.

**BMME 551. Medical Device Design I. 3 Credits.**

Student multidisciplinary teams work with local medical professionals to define specific medical device concepts for implementation.

**Rules & Requirements**

**Grading Status:** Letter grade.

**BMME 552. Medical Device Design II. 3 Credits.**

Device prototypes designed in the first course in series. Good manufacturing practices; process validation; FDA quality system regulations; design verification and validation; regulatory approval planning; and intellectual property protection.

**Rules & Requirements**

**Grading Status:** Letter grade.

**BMME 560. Medical Imaging II: X-Ray, CT, and Nuclear Medicine Systems. 3 Credits.**

Overview of medical imaging systems using ionizing radiation. Interaction of radiation with matter. Radiation production and detection. Radiography systems and applications. Tomography. PET and SPECT systems and applications.

**Rules & Requirements**

**Requisites:** Prerequisites, BIOS 550, BMME 410, and PHYS 128.

**Grading Status:** Letter grade.

**BMME 565. Biomedical Instrumentation I. 4 Credits.**

Graduate students or permission of the instructor. Topics include basic electronic circuit design, analysis of medical instrumentation circuits, physiologic transducers (pressure, flow, bioelectric, temperate, and displacement). This course includes a laboratory where the student builds biomedical devices.

**Rules & Requirements**

**Grading Status:** Letter grade.

**BMME 575. Practical Machine Learning for Biosignal Analysis. 3 Credits.**

This graduate level course will introduce practical machine learning concepts and tools, and will exemplify their application to the analysis of biological signals and images, including brain imaging, electrophysiology, and image recognition. MATH 347 recommended.

**Rules & Requirements**

**Requisites:** Prerequisites, COMP 116 and MATH 233; permission of instructor for students lacking the prerequisites.

**Grading Status:** Letter grade.

**BMME 576. Mathematics for Image Computing. 3 Credits.**

Mathematics relevant to image processing and analysis using real image computing objectives and provided by computer implementations.

**Rules & Requirements**

**Requisites:** Prerequisites, COMP 116 or 210 or 401, and MATH 233; a grade of C or better is required in all prerequisites.

**Grading Status:** Letter grade.

**Same as:** COMP 576.

**BMME 581. Microcontroller Applications II. 3 Credits.**

Advanced topics in microcontroller systems used for biomedical instruments. Problems of interfacing computers with biomedical systems are studied. Students collaborate to develop a new biomedical instrument. Platforms could include the use of digital signal processing (DSP) microcontrollers or field programmable gate arrays (FPGAs), and topics could include applications such as digital signal processing and high speed data acquisition to computers.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 375 and 385 or equivalent.

**Grading Status:** Letter grade.

**BMME 681. Human Factors Engineering and Quality Management Systems for Engineers. 3 Credits.**

This course teaches human factors engineering, risk assessment, and quality management systems. At the end of the course, students will be able to apply their knowledge to their senior design project and test for a six sigma green belt certification.

**Rules & Requirements**

**Grading Status:** Letter grade.

 **BMME 691H. Honors Thesis. 3 Credits.**

Research honors course. Prior approval needed from the chair or associate chair of the program for topic selection and faculty research mentor. Minimum GPA requirement, written report, and abstract requirements as set forth by the honors program.

**Rules & Requirements**

 **IDEAs in Action Gen Ed:** RESEARCH.

**Making Connections Gen Ed:** EE- Mentored Research.

**Grading Status:** Letter grade.

 **BMME 692H. Honors Thesis. 3 Credits.**

Research honors thesis continuation with required GPA, research topic selection with approved faculty mentor. Written abstract and report per honors program guidelines submitted by specific deadlines.

**Rules & Requirements**

 **IDEAs in Action Gen Ed:** RESEARCH.

**Making Connections Gen Ed:** EE- Mentored Research.

**Grading Status:** Letter grade.

 **BMME 697. BME Senior Design: Product Development. 3 Credits.**


This course is part of a three year sequence and it expands on the skills and knowledge gained in BM(M)E 398. Students continue to learn the process of engineering design and learn new skills to produce solutions for unmet medical needs. Majors only.

**Rules & Requirements**

 **IDEAs in Action Gen Ed:** FC-CREATE, COMMBEYOND.

**Requisites:** Prerequisites, BMME 398 and BMME 301 or 302; and two specialization or gateway electives.

**Grading Status:** Letter grade.

 **BMME 698. Biomedical Engineering Senior Design: Product Implementation and Strategy. 3 Credits.**

This course is part of a three-year sequence and it expands on the skills and knowledge gained in prior design courses. Students continue to learn the process of engineering design and learn new skills to produce solutions for unmet medical needs. Implementation phase of the senior design experience.

**Rules & Requirements**

 **IDEAs in Action Gen Ed:** RESEARCH.

**Making Connections Gen Ed:** CI, EE- Mentored Research.

**Requisites:** Prerequisites, BMME 398 and BMME 301 or 302; 2 gateway or specialization electives; Pre- or corequisite, 3 additional gateway or specialization electives.

**Grading Status:** Letter grade.

## Contact Information

Department of Biomedical Engineering

Visit Program Website (<http://www.bme.unc.edu>)

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