Biomedical Engineering (BME)

BME 201 Computer Methods in Biomedical Engineering (3 credit hours)
Students develop computer-based problem solving techniques using Excel and MATLAB to solve introductory problems in Biomedical Engineering. Emphasis is on developing solution algorithms, implementing these with spreadsheets and computer programming, and presenting results in a clear and concise manner. Students registered for BME 201 who fail to matriculate into BME will be dropped from the course.

Prerequisite: BME matriculated students
Typically offered in Fall only

BME 203/MSE 203 Introduction to the Materials Science of Biomaterials (3 credit hours)
This course introduces fundamental physical principles governing the structure, processing, properties and performance of metallic, ceramic and polymeric materials. Relationships are developed defining how mechanical, physical and chemical properties are controlled by microstructure and chemistry. Material failure modes are developed with an emphasis on biocompatibility and the applications/performance of materials in the human body. Basic aspects of material biocompatibility are presented, leading into studies of the current and future applications of biomaterials.

Prerequisite: C- or better in CH 101, CH 102 and PY 205
Typically offered in Fall and Spring

BME 204 Biomedical Measurements (3 credit hours)
This course will introduce students to modern topics in biomedical engineering and areas of emphasis in the biomedical engineering curriculum through the study and use of biomedical measurement tools. The course will include a lecture and a laboratory component.

Prerequisite: BME Majors
Typically offered in Fall and Spring

BME 205 Introduction to Biomedical Mechanics (4 credit hours)
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. Restricted to student in the Biomedical Engineering Department.

Credit cannot be received for both BME 205 and (CE 214 or MAE 206)
Typically offered in Spring only

BME 207 Biomedical Electronics (4 credit hours)
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.

Prerequisites: PY 208/209, BME Majors Only
Typically offered in Spring only

BME 209 Introduction to the Materials Science of Biomaterials (4 credit hours)
This course covers the chemistry, physics, and engineering theory underlying materials science and also discusses the diagnostic and analytical techniques necessary to assess these properties experimentally. This strong foundation prepares students to conceive and build better materials for a wide assortment of biomedical applications.

Co-req: PY 208/209. Pre-req: BME Students Only. Credit cannot be received for BME 209 and (MSE 200, MSE 201, MSE 203 or BME 203)
Typically offered in Fall only

BME 215 Biomedical Mechanics Laboratory (1 credit hours)
This laboratory is part of BME 205 - Biomedical Mechanics and complements it with relevant labs and examples. 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. Finally, the human arm will be studied to derive forces, moments, and kinematic properties during various exercises. BME student only.

Co-requisites: MAE 208
Typically offered in Spring only

BME 217 Biomedical Electronics Laboratory (1 credit hours)
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, biomedical applications.

Prerequisite: ECE 331, BME Majors
Typically offered in Spring only

BME 219 Materials Science of Biomaterials Lab (1 credit hours)
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.

Pre-requisite: MSE 200 or MSE 201 or MSE/BME 203. Credit cannot be received for both BME 219 and BME 209
Typically offered in Fall only

BME 295 Research in Biomedical Engineering for Undergraduates (1-3 credit hours)
Opportunity for faculty mentored research in biomedical engineering. Approved plan of work required with significant independent research culminating in a final paper. Students must identify an advisor or co-advisor from within the BME faculty with whom to work on a regular basis. The advisor and BME Undergraduate Affairs Committee must approve the student project prior to the student registering for the course.

R: BME Majors, Departmental Approval Required
Typically offered in Fall and Spring

BME 298 Biomedical Engineering Design and Manufacturing I (2 credit hours)
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.

Co-requisites: PY 208/209, BME Majors only
Typically offered in Fall only
BME 299  BME Design and Manufacturing I Lab  (1 credit hours)
BME 299 together with BME 252 or another course in CAD design fulfills the requirements of BME 298 Biomedical Engineering Design and Manufacturing I. In this course students learn some of the practical fundamentals of electronics manufacturing. Activities include use of bench equipment, soldering techniques, circuit board types, how to identify common electronic components and how they work in a circuit and simple C programming for microcontrollers.

Prerequisite: BME 252. Credit cannot be received for both BME 298 and BME 299
Typically offered in Fall only

BME 301/BMME 301  Human Physiology : Electrical Analysis  (4 credit hours)
This course includes a quantitative approach to human physiology from the biomedical engineering perspective with an emphasis on neural, sensory, muscle, and cardiac physiology. Autonomic and somatic motor control will be discussed. Engineering applications, including neural stimulators, 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.

Prerequisites: BIO 183, BM(M)E 201, [BME 210 or BM(M)E 207]
Typically offered in Fall only

BME 302  Human Physiology: Mechanical Analysis  (4 credit hours)
This course 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 muscles and larynx. In the course lab exercises, students investigate mechanical properties of fluids, electrolyte exchange in dialysis, spirometry and blood pressure measurement among other topics. The course culminates with the design of a novel laboratory experiment.

Prerequisite: BIO 183, [BM(M)E 205 or MAE 208], [BM(M)E 209 or BMME 150]
Typically offered in Spring only

BME 315  Biotransport  (3 credit hours)
Quantification and modeling of heat and mass transfer in biomedical systems. Topics include heat transfer rate equations, conservation of energy, steady-state and transient heat transfer, Brownian motion, Fick's laws, conservation of mass equations, molecular transport through membranes, porous media, Stokes-Einstein relations, boundary layer theory, mass transfer coefficients and hemodialysis.

Prerequisite: BIO 183 and BME/BMME 201 and BME/BMME 205 or MAE 208 and MA 341 or MA 331
Typically offered in Spring only

BME 325  Biochemistry for Biomedical Engineers  (3 credit hours)
An overview of how alterations in bioenergetics, enzyme catalysis, protein and membrane structure, carbohydrate, lipid and nucleic acid metabolism affect human health and how biomedical engineering tools are used to detect and monitor the problems by understanding these biochemical processes. 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, Technologies used to monitor/detect biochemical processes including clinical imaging modalities.

Prerequisite: CH 221, (BME 209 or BME 203)
Typically offered in Fall only

BME 335  Biomaterials  (3 credit hours)
Fundamental sciences behind the design and selection of biomaterials, including crystallography, polymer science, characterization, mechanical testing, and surface preparation. Integration of biomaterials into the body and its response, including inflammation and rejection. Semester-long research project.

Pre-req: BIO 183, (BME 209 or BME 203)
Typically offered in Spring only

BME 342  Analytical and Experimental Methods for Biomedical Engineers  (3 credit hours)
Experimental and analytic tools are developed and used to solve problems in biomedical engineering. Techniques include kinematic analysis, closed form and finite element analysis of stresses and strains in a body, and failure analysis. Transducers necessary for experimental analysis and testing are introduced. Students learn advanced software packages such as the finite element program ANSYS and the dynamic analysis program ADAMS to assist in their analyses.

Prerequisite: BME 201; MAE 208 or CE 215; MAE 214 or CE 313; MA 341
Typically offered in Spring only

BME 345  Biomedical Solid Mechanics  (3 credit hours)
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 the following: 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, Failure mechanisms.

P: BME 201 and (BME 205 or MAE 208) and (BME 209 or BME 203)
Credit cannot be received for BME 345 and (MAE 214 or CE 313)
Typically offered in Spring only

BME 355  Biocontrols  (3 credit hours)
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.

Prerequisite: MA 341; Corequisite: BME 311
Typically offered in Spring only
BME 365/BMME 365 Linear Systems in Biomedical Engineering (3 credit hours)

Pre-reqs: [BM(M)E 207 or BME 210], BM(M)E 201. Co-reqs: MA 341 or MA 331
Typically offered in Fall only

BME 375/BMME 375 Biomedical Microcontroller Applications (3 credit hours)
Overview of microcontroller-based systems, including applications, architecture, number systems, and languages. Students gain experience using a PIC-based microcontroller to input information from a user and output information using LEDs and LCD displays. Student will learn capabilities of the PIC through in class exercises and weekly programming assignments. Both assembly language and PIC-based C are used. Students develop a PIC-based heart rate monitor and work in pairs on a BME-related project of their choice.

Pre-reqs: [BM(M)E 207 or BME 210], BM(M)E 201. Co-reqs: BM(M)E 385 or BME 422
Typically offered in Fall only

BME 385/BMME 385 Bioinstrumentation (3 credit hours)
Fundamentals of biomedical instrument design and implementation. Sensing mechanisms, sensor microfabrication methods, sensor interfacing circuits, analog-to-digital conversion, biosignal capture and storage, embedded microprocessors, data compression methods, system integration and prototyping. Laboratory exercises using LabVIEW and MATLAB, supplement the topics presented in class lectures. Students build a sensor using cleanroom facilities in the BME department as part of a semester-long design project.

Pre-reqs: [BM(M)E 207 or BME 219], BM(M)E 201
Typically offered in Fall only

BME 395/BMME 395 Biomedical Engineering Design and Manufacturing II (2 credit hours)
Students will be required to continue their use of the tools learned in Biomedical Design and Manufacturing I in the context of modern design practices and manufacturing processes. The organizational and project management tools of modern design will be introduced, and a technical discussion of a modern manufacturing technology will be introduced each week.

Pre-reqs: BM(M)E 298, [BM(M)E 207 or BME 210], BM(M)E 201
Typically offered in Spring only

BME 412 Biomedical Signal Processing (3 credit hours)
Fundamentals of continuous- and discrete-time signal processing as applied to problems in biomedical instrumentation. Properties of biomedical signals and instruments. Descriptions of random noise and signal processes. Interactions between randombiomedical signals and systems. Wiener filtering. Sampling theory. Discrete-time signal analysis. Applications of Z-transform and discrete Fourier transform. Digital filter design methods for biomedical instruments. BME or MS or PHD; credit not allowed for both BME 412 and BME 512.

Pre-reqs: BM(M)E 365 or BME 311
Typically offered in Spring only

BME 418/BME 518/ECE 518/ECE 418 Wearable Biosensors and Microsystems (3 credit hours)
This course surveys the methods and application of wearable electronics and microsystems to monitor human biometrics, physiology, and environmental conditions. Topics covered include wearable electrocardiograms, blood-glucose monitors, electronic tattoos, wearable energy harvesting, “smart” clothing, body area networks, and distributed population networks. Critical comparison of different sensor modalities, quantitative metrics, and how their limitations in realistic applications define the selection, design, and operation criteria of one type of sensor over another will be considered.

Prerequisite: Senior standing
Typically offered in Fall only

BME 425/BME 525 Bioelectricity (3 credit hours)
Quantitative analysis of excitable membranes and their signals, including plasma membrane characteristics, origin of electrical membrane potentials, action potentials, voltage clamp experiments, the Hodgkin-Huxley equations, propagation, subthreshold stimuli, extracellular fields, membrane biophysics, and electrophysiology of the heart. Design and development of an electrocardiogram analysis system.

Prerequisite: BME 302 or (ZO 421 and a course in electrical circuits)
Typically offered in Spring only

BME 444/BME 544 Orthopaedic Biomechanics (3 credit hours)
Students study human body kinematics, force analysis of joints, and the structure and composition of biological materials. Emphasis is placed on the measurement of mechanical properties and the development and understanding of models of biological material mechanical behavior.

P: BM(M)E 301, BM(M)E 302, [BM(M)E 345 or MAE 214 or CE 313]
Typically offered in Fall only

BME 451/BMME 451 Biomedical Engineering Senior Design I (3 credit hours)
This course encompasses the project proposal and design concepts, including: individual pre-proposals, team proposals, project planning, scheduling, needs assessment, product requirements, competitive landscape and patent review, business risks, design concepts, and phase reviews. BME majors only.

Pre-reqs: BM(M)E 301, BM(M)E 302, [BM(M)E 398 or BME 352], 2 Gateway Electives: BME 3*5
Typically offered in Fall only
BME 452/BMME 452 Biomedical Engineering Senior Design II (3 credit hours)
This course is a continuation of BME 451 moving from proposal and concepts into manufacturing, prototyping, and testing. The deliverables in this course include: detailed manufacturing specifications, biomaterials review, supplier identification, product feasibility, issues tracking, manufacturing planning, bill of materials, product risks, qualification protocol, IP disclosure, process validation planning, regulatory review, design history file audit, lessons learned, and phase reviews.
Prerequisite: BME 451, BME Majors

BME 462 Biomaterials Characterization (3 credit hours)
Introductory laboratory experience focused on integrating engineering and biological principles by exploring key topics in biomaterials. Topics include evaluation and interpretation of experimental results, modeling and testing of tissues and cells, and biomaterial/tissue, cell interactions. BME and MSE Majors only; Juniors and Seniors.
Pre-reqs: [BM(M)E 325 or BCH351 or BCH 451], [BM(M)E 335 or MSE 485] and BME Majors.
Typically offered in Spring only

BME 466/TE 566/BME 566/TE 466 Polymeric Biomaterials Engineering (3 credit hours)
In-depth study of the engineering design of biomedical polymers and implants. Polymeric biomaterials, including polymer synthesis and structure, polymer properties as related to designing orthopedic and vascular grafts. Designing textile products as biomaterials including surface modification and characterization techniques. Biodegradable polymers.
Prerequisite: PY 208 and (TE 200 or CH 220 or CH 221 or CH 225) and (MAE 206 or CE 214)
Typically offered in Fall only

BME 467/TE 467 Mechanics of Tissues & Implants Requirements (3 credit hours)
Application of engineering and biological principles to understand the structure and performance of tendons, ligaments, skin, and bone; bone mechanics; viscoelasticity of soft biological tissues; models of soft biological tissues; mechanics of skeletal muscle; and tissue-derived devices as well as interfaces between native tissues and synthetic devices.
Prerequisite: (ZO 160 or BIO 183) and (MAE 214 or CE 225)
Typically offered in Spring only

BME 481 Quality Management Systems for Engineers (3 credit hours)
This course is designed for biomedical engineering students who plan to work in industry. The course covers industry related topics including team work, conflict resolution, manufacturing and specifications, gap analysis, and root cause of analysis. Design topics including design of experiments, and standards and regulations relevant to the biomedical engineering profession are also covered. Lean and six sigma are taught with an option to test for a six sigma green belt if a six sigma project is completed in the following semester.
Co-reqs: BMME 697 or BME 451
Typically offered in Fall only

BME 483/BEC 483/BME 583/BEC 583 Tissue Engineering Technologies (2 credit hours)
In this half-semester laboratory module, students will gain practical experience with two key elements of tissue engineering: tissue building and angiogenesis. Using advanced culture techniques, students will construct a complex living tissue that closely resembles its natural counterpart, then assess its ability to support ingrowth of capillaries (angiogenesis). The effects of different biomaterials and angiogenic factors will be evaluated. The engineered tissue will be embedded, sectioned and stained for histological analysis.
Prerequisite: BIT 466/566 or permission of instructor
Typically offered in Fall only

BME 484/BME 584 Fundamentals of Tissue Engineering (3 credit hours)
This course covers essential concepts of organ and tissue design and engineering using living components, including cell-based systems and cells/tissues in combination with biomaterials, synthetic materials and/or devices. Topics include: In vivo tissue structure and function; Isolation and culture of primary cells and stem cells; Principles of cellular differentiation; Mass transport processes in cell culture systems; Design, production and seeding of scaffolds for 3D culture; Design of bioreactors to support high-density cell growth; State-of-the-art engineered tissue systems; Clinical translation; and Ethics.
Prerequisite: BIO 183, CH 221, and (MAE 201 or MSE 301 or CHE 315 or TE 303 or BME 315 or BME 325)
Typically offered in Spring only

BME 490 Special Topics in Biomedical Engineering (1-4 credit hours)
Offered as needed for presenting material not normally available in regular BME Department courses or for new BME courses on a trial basis.
Typically offered in Fall, Spring, and Summer

BME 491 Biomedical Engineering Honors Thesis I (3 credit hours)
First in a two-semester sequence of research courses that partially fulfills the requirements for graduation with departmental honors. Prior approval needed for enrollment. Students should identify a research mentor and research topic before applying. Minimum GPA requirement and written report are required. The course does not meet a graduation requirement, and can only be used to meet the requirements of graduation with departmental honors.
Typically offered in Fall and Spring

BME 492 Biomedical Engineering Honors Thesis II (3 credit hours)
Second in a two-semester sequence of research courses that partially fulfills the requirements for graduation with departmental honors. Students work with a mentor on an independent research project. Minimum GPA requirement and written report are required. The course does not meet a graduation requirement if used to meet the requirements of graduation with departmental honors.
Prerequisite: BME 491 and project continuation approval by the BME Undergraduate Research Committee
Typically offered in Fall and Spring
BME 498 Undergraduate Research in Biomedical Engineering (3 credit hours)
Opportunity for hands-on faculty mentored research project in biomedical engineering. Course may be a stand-alone project completed in one semester/summer or serve as part of a two-semester project. Approved plan of work required with significant independent research culminating in a final paper and presentation at the NC State Undergraduate Research Symposium or other appropriate venue. Students must identify an advisor from within the BME faculty with whom to work on a regular basis. The advisor must approve the student prior to the student registering for the course. The BME Undergraduate Coordinator must approve the use of the course as a restricted elective for the BME degree. Departmental Approval Required. Individualized/Independent Study and Research courses require a Course Agreement for Students Enrolled in Non-Standard Courses be completed by the student and faculty member prior to registration by the department.

Typically offered in Fall and Spring

BME 501 Biomedical Innovation and Entrepreneurship I - Needs Discovery (4 credit hours)
This course utilizes clinical immersion to identify medical device and other healthcare opportunities. Students will be exposed to diverse healthcare environments and learn to triage opportunities based on financial, regulatory and intellectual property landscapes. Guest lectures will feature experts in the medical device, pharmaceutical and healthcare industries as well as local entrepreneurs.

Prerequisite: Graduate Standing; R: Restricted to students enrolled in the M.S. Biomedical Engineering Program
Typically offered in Summer only

BME 502 Biomedical Innovation and Entrepreneurship II - Design and Regulation (4 credit hours)
This course teaches path-to-market concepts including regulatory aspects unique to medical devices and pharmaceuticals. Topics include detailed analyses of Phase I-IV clinical trials, 510(k) and PMA approvals, Investigational Device Exemption (IDE) Investigational New Drug (IND) application, Good Laboratory Practices (GLP) and clinical research organizations (CROs). Students will participate in frequent visits to local biotech companies. Guest lectures will feature experts in FDA processes, clinical research and early stage biotech ventures.

Prerequisite: Graduate Standing; R: Restricted to students enrolled in the M.S. Biomedical Engineering Program
Typically offered in Fall only

BME 503 Biomedical Innovation and Entrepreneurship III - Product Development (4 credit hours)
This course covers product development and project management for new biomedical-related products from accessing various streams of funding to allocation of resources for rapid prototyping and scale-up manufacturing. Students will visit local biotech companies and prototyping facilities. A guest lecture series will feature best practices from entrepreneurs and industry practitioners.

Prerequisite: Graduate Standing; R: Restricted to students enrolled in the M.S. Biomedical Engineering Program
Typically offered in Spring only

BME 512 Biomedical Signal Processing (3 credit hours)

Prerequisite: BME 311, and ST 370 or ST 371
Typically offered in Spring only

BME 518/ECE 518/ECE 418/BME 418 Wearable Biosensors and Microsystems (3 credit hours)
This course surveys the methods and application of wearable electronics and microsystems to monitor human biometrics, physiology, and environmental conditions. Topics covered include wearable electrocardiograms, blood-glucose monitors, electronic tattoos, wearable energy harvesting, “smart” clothing, body area networks, and distributed population networks. Critical comparison of different sensor modalities, quantitative metrics, and how their limitations in realistic applications define the selection, design, and operation criteria of one type of sensor over another will be considered.

Prerequisite: Senior standing
Typically offered in Fall only

BME 522/ECE 522 Medical Instrumentation (3 credit hours)
Fundamentals of medical instrumentation systems, sensors, and biomedical signal processing. Example instruments for cardiovascular and respiratory assessment. Clinical laboratory measurements, therapeutic and prosthetic devices, and electrical safety requirements. Students should have background in electronics design using operational amplifiers.

Typically offered in Spring only

BME 525/BME 425 Bioelectricity (3 credit hours)
Quantitative analysis of excitable membranes and their signals, including plasma membrane characteristics, origin of electrical membrane potentials, action potentials, voltage clamp experiments, the Hodgkin-Huxley equations, propagation, subthreshold stimuli, extracellular fields, membrane biophysics, and electrophysiology of the heart. Design and development of an electrocardiogram analysis system.

Prerequisite: BME 302 or (ZO 421 and a course in electrical circuits)
Typically offered in Spring only

BME 540 Nanobiotechnology Processing, Characterization, and Applications (3 credit hours)
Topics at the interface of nanoscale science and biotechnology will be discussed. Chemical, physical, and biological properties of nanostructured biomaterials, devices, and systems. Lectures and problem-based learning will be used to present development of nanobiotechnology-enhanced materials and devices.

Prerequisite: BIO 183 and PY 212
Typically offered in Spring only
BME 543 Cardiovascular Biomechanics (3 credit hours)
Engineering principles are applied to the cardiovascular system. Anatomy of cardiovascular system; form and function of blood and blood vessels. Electric analogs; continuum mechanics with derivation of equations of motion; and constitutive models of soft tissue mechanics, with attention to normal, diseased, and adaptive processes. Programming project required.

BME 544/BME 444 Orthopaedic Biomechanics (3 credit hours)
Students study human body kinematics, force analysis of joints, and the structure and composition of biological materials. Emphasis is placed on the measurement of mechanical properties and the development and understanding of models of biological material mechanical behavior.

BME 550 Medical Imaging: Ultrasonic, Optical, and Magnetic Resonance Systems (3 credit hours)
Physical and mathematical foundations of ultrasonic, optical, and magnetic resonance imaging systems in application to medical diagnostics. Each imaging modality is examined on a case-by-case basis, highlighting the following critical system characteristics: (1) underlying physics of the imaging system, including the physical mechanisms of data generation and acquisition; (2) image creation, and (3) basic processing methods of high relevance, such as noise reduction.

Prerequisite: BME 412, ST 370 or ST 371, and PY 208
Typically offered in Fall only

BME 551 Medical Device Design (3 credit hours)
Student multidisciplinary teams work with local medical professionals to define specific medical device concepts for implementation. Medical specialty immersion with clinical departments at local medical centers; design input based on stakeholder-needs assessment; market analysis and intellectual property review; new medical devices with broad markets; design output and device specification; product feasibility and risk assessment; design for medical device manufacturing.

Typically offered in Fall only

BME 552 Medical Device Design II (3 credit hours)
Student groups build and test prototypes of devices designed in the first course of this series. Good manufacturing practices; process validation; FDA quality system regulations; design verification and validation; regulatory approval planning; and intellectual property protection. Students will work with local patent attorneys and/or agents to draft a patent application. The final prototypes will be evaluated by clinicians for potential use with patients.

BME 555 Medical Device Design (3 credit hours)
In-depth study of the engineering design of biomedical polymers and implants. Polymeric biomaterials, including polymer synthesis and structure, polymer properties as related to designing orthopedic and vascular grafts. Designing textile products as biomaterials including surface modification and characterization techniques. Biodegradable polymers.

Prerequisite: PY 208 and (TE 200 or CH 220 or CH 221 or CH 225) and (MAE 206 or CE 214)
Typically offered in Fall only

BME 556/TE 466/BME 466/TE 566 Polymeric Biomaterials Engineering (3 credit hours)

In-depth study of the engineering design of biomedical polymers and implants. Polymeric biomaterials, including polymer synthesis and structure, polymer properties as related to designing orthopedic and vascular grafts. Designing textile products as biomaterials including surface modification and characterization techniques. Biodegradable polymers.

Prerequisite: BIT 466/566 or permission of instructor
Typically offered in Fall only

BME 583/BEC 583/BME 483/BEC 483 Tissue Engineering Technologies (2 credit hours)
In this half-semester laboratory module, students will gain practical experience with two key elements of tissue engineering: tissue building and angiogenesis. Using advanced culture techniques, students will construct a complex living tissue that closely resembles its natural counterpart, then assess its ability to support ingrowth of capillaries (angiogenesis). The effects of different biomaterials and angiogenic factors will be evaluated. The engineered tissue will be embedded, sectioned and stained for histological analysis.

Prerequisite: BIT 466/566 or permission of instructor
Typically offered in Fall only

BME 584/BME 484 Fundamentals of Tissue Engineering (3 credit hours)
This course covers essential concepts of organ and tissue design and engineering using living components, including cell-based systems and cells/tissues in combination with biomaterials, synthetic materials and/or devices. Topics include: In vivo tissue structure and function; Isolation and culture of primary cells and stem cells; Principles of cellular differentiation; Mass transport processes in cell culture systems; Design, production and seeding of scaffolds for 3D culture; Design of bioreactors to support high-density cell growth; State-of-the-art engineered tissue systems; Clinical translation; and Ethics.

Prerequisite: BIO 183, CH 221, and (MAE 201 or MSE 301 or CHE 315 or TE 303 or BME 315 or BME 325)
Typically offered in Spring only

BME 590 Special Topics in Biomedical Engineering (1-6 credit hours)
A study of topics in the special fields under the direction of the graduate faculty.

Prerequisite: Senior or Graduate standing in Engineering or physical or biological sciences or textiles
Typically offered in Fall, Spring, and Summer

BME 620 Special Problems in Biomedical Engineering (1-6 credit hours)
Selection of a subject by each student on which to do research and write a technical report on the results. Subject may pertain to the student's particular interest in any area of study in biomedical engineering.

Prerequisite: Graduate standing in BME
Typically offered in Fall, Spring, and Summer
BME 650  Internship in Biomedical Engineering  (1 credit hours)
Students obtain professional experience through advanced engineering work in industrial and commercial settings under joint supervision of a member of the graduate faculty and an outside professional.

Prerequisite: Graduate standing in BME
Typically offered in Summer only

BME 685  Master's Supervised Teaching  (1-3 credit hours)
Teaching experience under the mentorship of faculty who assist the student in planning for the teaching assignment, observe and provide feedback to the student during the teaching assignment, and evaluate the student upon completion of the assignment.

Prerequisite: Master's student
Typically offered in Fall, Spring, and Summer

BME 693  Master's Supervised Research  (1-9 credit hours)
Instruction in research and research under the mentorship of a member of the Graduate Faculty.

Prerequisite: Master's student
Typically offered in Fall and Spring

BME 695  Master's Thesis Research  (1-9 credit hours)
Thesis research.

Prerequisite: Master's student
Typically offered in Fall, Spring, and Summer

BME 696  Summer Thesis Research  (1 credit hours)
For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

Prerequisite: Master's student
Typically offered in Fall, Spring, and Summer

BME 699  Master's Thesis Preparation  (1-9 credit hours)
For students who have completed all credit hour requirements and full-time enrollment for the master's degree and are writing and defending their thesis.

Prerequisite: Master's student
Typically offered in Fall, Spring, and Summer

BME 790  Advanced Special Topics in Biomedical Engineering  (1-6 credit hours)
A study of topics in advanced or emerging special areas under the direction of the graduate faculty. Experimental doctoral level courses.

Prerequisite: Graduate standing in engineering, physical, or biological sciences or textiles
Typically offered in Fall, Spring, and Summer

BME 802  Advanced Seminar in Biomedical Engineering  (1 credit hours)
Elaboration of advanced subject areas, techniques and methods related to professional interest through presentations of personal and published works; opportunity for students to present and critically defend ideas, concepts, and inferences; opportunity for distinguished scholars to present results of their work. Discussions to uncover analytical solutions and analogies between problems in biomedical engineering and other technologies, and to present relationship of biomedical engineering to society.

Prerequisite: Doctoral student in BME or other engineering, physical science, or biological science majors, or textiles
Typically offered in Fall and Spring

BME 885  Doctoral Supervised Teaching  (1-3 credit hours)
Teaching experience under the mentorship of faculty who assist the student in planning the teaching assignment, observe and provide feedback to the student during the teaching assignment, and evaluate the student upon completion of the assignment.

Prerequisite: Doctoral student
Typically offered in Fall, Spring, and Summer

BME 890  Doctoral Preliminary Examination  (1-9 credit hours)
For students who are preparing for and taking written and/or oral preliminary exams.

Prerequisite: Doctoral student
Typically offered in Summer only

BME 893  Doctoral Supervised Research  (1-9 credit hours)
Instruction in research and research under the mentorship of a member of the Graduate Faculty.

Prerequisite: Doctoral student
Typically offered in Fall and Spring

BME 895  Doctoral Dissertation Research  (1-9 credit hours)
Dissertation research.

Prerequisite: Doctoral student
Typically offered in Fall, Spring, and Summer

BME 896  Summer Dissertation Research  (1 credit hours)
For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

Prerequisite: Doctoral student
Typically offered in Summer only

BME 899  Doctoral Dissertation Preparation  (1-9 credit hours)
For students who have completed all credit hour, full-time enrollment, preliminary examination, and residency requirements for the doctoral degree, and are writing and defending their dissertations.

Prerequisite: Doctoral student
Typically offered in Fall, Spring, and Summer