**Course Catalog**

**GRADUATE COURSES**

### Required Core Courses

**BMES 5054 / 605  Quantitative Cell Physiology**


**BMES 5064 / 606  Quantitative Organ Systems Physiology**


### Additional Core Courses

**BMES 5024 / 602 (BMVS 5224)  Biomedical Engineering & Human Disease**

Comprehensive overview of a variety of human diseases, including, neurological disorders, cardiovascular disease, infectious disease, and cancer, designed primarily for graduate students majoring in engineering and other related areas who have a long-term academic and professional goal in the field of biomedical engineering and life sciences. Introduction to state-of-the-art biomedical engineering approaches used for the study of early detection/diagnosis, treatment and prevention of human disease. Graduate standing required. (3H, 3C)

**BMES 5044 (CHE 5044) (BSE 5044)  Engineering Mathematics**

Introduction to numerical solutions of partial differential equations using the finite element method in one-, two-, and three-dimensions with direct relevance to chemical engineering, biological systems engineering and biomedical engineering and sciences. Partial differential equations and ordinary differential equations using finite differences, model parameter sensitivity analysis, optimization, and data analysis. Pre-requisite: Graduate Standing required. (3H, 3C)

### Introductory Courses

**BMES 5124 / 612 (ESM 5224)  Advanced Musculoskeletal Biomechanics**

Skeletal anatomy and mechanics. Muscle anatomy and mechanics. Theory and application of electromyography. Motion and force measuring equipment and techniques. Inverse dynamics modeling of the human body. Current topics in musculoskeletal biomechanics research. (3H, 3C)

**BMES 5134 / 613  Biomechanics and Simulation of Movement I**

Key topics in movement biomechanics, including muscle physiology and mechanics, neural control, kinematic and dynamic modeling, and dynamic simulation. Discussion of real-life application in medicine and sports, and practical experience using engineering equipment (motion capture and EMG) and software used in research and industry to analyze human movement. Pre-requisite: Graduate Standing required. (3H, 3C)

**BMES 5144 / 614  Biomechanics and Simulation of Movement II**

Advanced topics in movement biomechanics and computational analyses of human movement, including advanced muscle modeling, motor control theories, dynamic simulation and optimization, and neural
interfaces. Discussion of fundamental research underpinnings and clinical applications. Practical simulation labs and project-based exploration of dynamic and analyses. Pre: Graduate standing. (3H, 3C)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMES 5164 / 616 (ME 5754)</td>
<td><strong>Advanced Impact Biomechanics</strong></td>
<td>A review of impact biomechanics and critical investigation of the impact response of the human body. Participants will study the dynamic response of the head, neck, chest, abdomen, upper extremities, and lower extremities. Real world examples from automobile safety, military applications, and sport biomechanics. (3H, 3C)</td>
</tr>
<tr>
<td>BMES 5174 / 617</td>
<td><strong>Biomechanics of Crash Injury Prevention</strong></td>
<td>Principles of design and analysis of crash injury prevention methods in vehicle crashes. The course encompasses three major focus areas for occupant protection in crashes: crash energy absorption in (1) the vehicle structure, (2) the occupant, and (3) the occupant restraints. Topics include the biomechanics of impact injury, analysis of occupant response in crash tests, vehicle crash kinematics, modeling of vehicle impact response, modeling of human impact response, and occupant restraint design. Graduate standing required. (3H, 3C)</td>
</tr>
<tr>
<td>BMES 5184 / 618</td>
<td><strong>Injury Physiology</strong></td>
<td>Introduction to the physiology of injury. Focus on the pathophysiology, mechanisms, and outcomes of injury in humans. Explores injury physiology at the organ, tissue, and cellular level. Topics include physiology of injury to the peripheral and central nervous systems, the musculoskeletal system, the pulmonary system, the abdomen, and the eye. Includes the injury physiology of adults as well as the special populations of children, pregnant females, and the elderly. Graduate standing required. (3H, 3C) Prereq: BMES 5054, 5064 Co: BMES 5164</td>
</tr>
<tr>
<td>BMES 5214 / 621 (ISE 5614)</td>
<td><strong>Human Physical Capabilities</strong></td>
<td>Focuses on the modeling, analysis, and evaluation of industrial workplaces with emphasis on the physical demands placed on and the capabilities of workers. Topics covered include: physiology, anthropometry, bioinstrumentation, and biomechanics. Students will learn and apply a range of contemporary analytical and assessment methods. Graduate standing required. (3H, 3C)</td>
</tr>
<tr>
<td>BMES 5244 / 624</td>
<td><strong>Biofluids</strong></td>
<td>Fluid dynamics of physiological systems with focus on the cardiovascular and the respiratory systems. The course will address: the heart, arterial blood vessels, airways; description of cardiac and pulmonary circulation; anatomy and function of the heart; anatomy and function of the respiratory system; mechanics of soft tissues; review of basic fluid mechanics; continuum mechanics and constitutive modeling; rheology of blood, Newtonian and non-Newtonian; Viscous flow in vessels, Navier-Stokes; mathematical analysis of pulsatile flow; pulse-wave propagation through vessels; particulate flows and particle transport in airways. Pre: Graduate standing. (3H, 3C) Prereq: ME 3404, ESM 3015</td>
</tr>
<tr>
<td>BMES 5304 / 630 (CHE 5304)</td>
<td><strong>Biological Transport Phenomena</strong></td>
<td>The fundamental principles of mass transport phenomena will be introduced and applied to the characterization of transport behavior in biological systems (e.g., cell, tissues, organs, people). Topics will include active, passive, and convective molecular transport mechanisms. These fundamentals will be used to develop analytical and predictive models that describe phenomena such as oxygen transport, kidney function, systemic drug delivery, and design of extracorporeal devices. Graduate standing required. (3H, 3C) Prereq: CHE 3114, CHE 3044, CHE 3144, ME 3304, ME 3404</td>
</tr>
<tr>
<td>BMES 5314 / 631</td>
<td><strong>Introduction to Regenerative Medicine</strong></td>
<td>Current state of the field of regenerative medicine with specific emphasis on the technological challenges that limit the efficacy and clinical translation of engineered tissues and therapies. Life science (e.g., cell biology, organ physiology, biochemical methods) and engineering perspectives (e.g., stem cells, biologically-inspired materials, gene therapies) Pre-requisite: Graduate Standing required. (3H, 3C)</td>
</tr>
<tr>
<td>BMES 5434 / 643 (CHE 5214)</td>
<td><strong>Polymeric Biomaterials</strong></td>
<td>Topics include polymer design and processing, inflammatory responses to polymers, interaction of blood</td>
</tr>
</tbody>
</table>
with polymeric materials, and the effect of mechanical, chemical, and surface properties of polymers on cells. The culmination of this course will provide students with the knowledge to successfully design polymer-based biomaterials, drug-delivery devices, and bio-implants. Graduate standing required. (3H, 3C)

**BMES 5514 / 651 (ME 5714)  Digital Signal Processing for Mechanical Measurements**
The fundamentals of digital signal processing of data experimentally obtained from mechanical systems will be covered. Attention will be given to the data acquisition, A/D conversion, aliasing, anti-aliasing filtering, sampling rates, valid frequency ranges, windowing functions, leakage, and various transform methods. Special attention will be given to random, transient, and harmonic function data processing. Various methods of estimation of the frequency response function (FRF) will be explored. The estimation methods will be assessed as to their impact on FRF estimation errors. (3H, 3C)

**BMES 5525-5526 / 652 (ECE 5605-5606)  Stochastic Signals and Systems**
Engineering applications of probability theory, random variables and random processes. Time and frequency response of linear systems to random inputs using both classical transform and modern state space techniques. (3H, 3C) Prereq: STAT 4714

**BMES 5554 / 655  Biomedical Signal and Image Processing**
The mathematical theory underlying the processing of one and two dimensional signals, including Fourier transforms, sampling, quantization, correlation, and filtering. For images, the topics of segmentation, restoration, enhancement, color, and registration will be explored. Matlab projects will be utilized extensively, with an emphasis on biomedical signals and images. Graduate standing required. (3H, 3C)

**BMES 5714 / 671  Biomedical Microdevices**
The goal of this course is to build the foundation necessary for engineering research in micro- and nano-biotechnology. The course will be broken down into four major area: micro- and nano- fabrication techniques, the fundamentals of microfluidics, micro- and nano- particle manipulation, and engineering aspects of cells and their membranes. The culmination of the course will provide students the knowledge required to create biomedical micro- and nano- devices with a focus on the unique physics, biology and design aspects at these scales. Students will be expected to know undergraduate engineering, physics, and calculus. Graduate standing required. (3H, 3C)

**BMES 5764 / 676 (ESM 5764, ME 5764)  Modeling MEMS and NEMS**
Modeling MEMS and NEMS is about the construction, analysis, and interpretation of mathematical and computational models microelectromechanical and nanoelectromechanical systems (MEMS and NEMS). A goal throughout the course will be to develop a physical intuition for the fundamental phenomena at these small scales. The material covered will be broad and multidisciplinary including: dimensional analysis and scaling; a review of continuum mechanics; fluid dynamics, elasticity, thermal transport and electromagnetism at the micro and nano scales; the modeling of a variety of new MEMS/NEMS devices; and approaches beyond the continuum theory including stochastic and deterministic methods. Graduate standing required. (3H, 3C)

**Advanced Courses**

**BMES 6064 / 706  Clinical Rotation**
The course gives the student both a broad view of the use of engineering principles in medicine and general clinical care, together with an in-depth study of a particular aspect of medicine under the direct supervision of a physician. The student is allowed to observe the operation and maintenance of various clinical modalities, systems, and devices under the guidance of a working engineer or technician. The student participates in clinical rounds and image reading sessions to gain insight into the actual operation and needs of departments using medical imaging modalities. Pre: BME Ph.D. graduate students who have finished first year of study. (2C)

**BMES 6164 / 716 (ME 6754)  Computational Modeling in Impact Biomechanics**
Dynamic modeling of the human body subjected to transient impact loading. A combination of finite element analysis and multi-body simulated techniques. Utilized software packages with dynamic solvers. Applications include computer-aided design for automobile safety, sports biomechanics, and military restraint systems. (3H, 3C) Prereq: BMES 5164, ME 5754

**BMES 6174 / 717 Advanced Human Modeling: Injury and Tissue Biomechanics**
Serves as a continuation of Impact biomechanics (BMES 5164) and computational biomechanics (BMES 6164). Basics of the finite element method as it applies to high-rate phenomena. Focus will be on practical problems and the use of commercial codes for solving vehicle crashworthiness and biomechanics problems. Theory will be presented when it is useful for application to the problem. Real world examples from biomedical engineering, automobile safety, military applications, and sport biomechanics are used. (3H, 3C) Prereq: BMES 5164, ME 5754, BMES 6164, ME 6754

**BMES 6504 / 750 Medical Imaging I**
Medical Imaging I provides an introduction to basic imaging science and to two medical imaging disciplines: Radiography and Nuclear Medicine. Topics include: an overview of the underlying physical processes; data acquisition, sampling, and quantization; image reconstruction techniques; relationships between the various modalities; medical imaging parameters (resolution, contrast, and noise), and medical applications. Graduate standing required. (3H, 3C)

**BMES 6514 / 751 Medical Imaging II**
Medical Imaging II provides an introduction to three medical imaging modalities: Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Ultrasound. Potential topics to be covered under emerging technologies are TeraHertz Imaging, Optical Imaging, and Molecular Imaging. Each imaging modality will cover the underlying physical processes; data acquisition, sampling, quantization; image reconstruction techniques; relationship between the various modalities; and clinical and industrial applications. Each modality is reviewed in the context of its underlying physical processes, as well as a common model describing such basic imaging parameters as resolution, contrast, and noise. Graduate standing required. (3H, 3C) Prereq: BMES 5554

**Additional Degree Fulfillment Coursework**

**BMES 5944 / 694 Seminar**
Required every semester. (1H, 1C)

**BMES 5994 Research & Thesis (VT Campus)**
Sign up under advisor's section. Variable credit: (1 – 18C)

**BMES 7994 Research & Dissertation (VT Campus)**
Sign up under advisor's section. Variable credit: (1 – 18C)

**BMES 797 / 798 Research (WFU Campus)**
Variable credit: (1 – 9)

**BMES “TO” Thesis Only (WFU Campus)**
Variable credit: (1 – 9)

**BMES 5974 / 697 Independent Study**
Variable credit (normally 3C), Pass-Fail only.

**BMES 5984/6984 / 698 Special Study**
Variable credit (normally 3C)