UNIVERSITY OF CALGARY
Biomedical Engineering Graduate Program

UNIVERSITY OF CALGARY COURSE LEGEND	
ENCI = Civil Engineering Department	ENME = Mechanical Engineering Department
ENCH/ENPE = Chemical & Petro Engineering Department	BMEN = BME Graduate Program
MDSC – Cumming School of Medicine	ENEL = Electrical and Computer Engineering Department
ENGO = Geomatics Engineering Department	KNES = Faculty of Kinesiology

IMPORTANT….

If you would like to take an option (technical elective) course that is NOT on this approved list of options, students MUST provide the BME GP office, Program Coordinator, Lisa Mayer, bmegrad@ucalgary.ca via email a copy of an **official course outline** for consideration, and permission to count towards your MSc or PhD degree course requirements.

FALL 2020 – Approved by the BME Graduate Program		
COURSE TITLE / INSTRUCTOR	**COURSE**	**COURSE Description**
Dr. Elena Di Martino Dr. Roman Krawetz	**BMEN 600** **CORE COURSE**	NOTE: Mandatory Courses for BME Graduate Program Students **Biomedical Engg Foundations** An introduction to core concepts of Biomedical Engineering including an introduction to biomedical engineering fundamentals. Course allows students to select between a biology focused or an engineering focused fundamental module to complement previous course work (with approval of course instructor).
Dr. Derrick Rancourt	**BMEN 602** **CORE COURSE**	NOTE: Mandatory Courses for BME Graduate Program Students **Biomedical Engg Core I** Topics may include an introduction to a) biomedical engineering research, research integrity and ethics, b) career paths and progression in biomedical engineering and c) oral research communication skills.
Molecular, Cellular and Tissue BioEngineering Dr. Kristina Rinker	BMEN 619.15 / BMEN 585	Concepts, calculations, and methodologies in molecular, cellular and tissue engineering will be discussed and applied to solve problems in the areas of molecular diagnostics, pharmaceuticals, nanomedicine and regenerative medicine. Topics include cell biology and culture, stem cells, bioreactors, biomaterials, drug delivery, fluid dynamics, kinetics, and diffusion. Prerequisite(s): Fourth- or fifth-year standing in the Engineering program of choice. Antirequisite(s): Credit for Biomedical Engineering 585 and any of Biomedical Engineering 407, Biomedical Engineering 519.9, and Chemical Engineering 541 will not be allowed

Machine Learning for Biomedical Engineers and Biomechancis Dr. Art Kuo	BMEN 619.18	Introduction to machine learning with examples and applications drawn from biomedical engineering, biomechanics, and related fields. Computational approaches to classification, dimensionality reduction, and pattern identification from large data sets. Fundamental concepts of function approximation and statistics, algorithms for supervised learning and unsupervised learning. Linear regression, logistic regression, support vector machine, neural networks. Adaptation algorithms, gradient descent. K-means clustering, principal components analysis. Brief introduction to reinforcement learning and control.
Experimental Design Instructor: Dr. Laura Curiel	ENEL 619.85	Introduction to the design of experiments: problem definition, selecting variables, determining sample size, randomization, nuisance variables. Tools for data analysis will be taught for designing and analyzing data from a simple comparison of populations, analysis of variance (multi-variable comparison), controlling nuisance variables, factorial designs, regression and data visualization techniques. An introduction to basic qualitative research methods in engineering will be also covered. The course will use a case-study approach and may include problems centered in biomedical applications and from specific research problems from the students.
Biostatistical Methods Dr. Rob Deardon	VETM 605 / MDCH 605	Introductory course on how to design veterinary research projects and analyze the resultant data. Emphasis is placed upon formulating testable research questions, evaluating the appropriateness of different research designs, planning a well-designed experiment or clinical trial, performing statistical analyses on the data, and presenting the results in a scientific manner
Bone/Joint Biomechanics Osteoarthritis Dr. Walter Herzg (Course Coordinator) Dr. Brent Edwards Dr. David Hart Dr. Roman Krawetz	KNES 644 (Formerly KNES 603.22)	An examination of bone and joint biomechanics as they relate to bone fracture, joint injuries, and diseases with an emphasis on osteoarthritis. Basic bone, ligament, cartilage, and muscle structure and function will be discussed in the context of healthy tissues and in aging, disease, and post-trauma. Animal models of disease are explored
Cardiovascular Physiology Dr. Robert Rose	MDSC 629.01 (H)	A mechanistic, organ-system, physiological approach to the heart and vascular system designed for graduate and upper-level undergraduate students in the medical sciences, kinesiology, and bioengineering. Topics will include: The Cardiac Cycle, Assessment of Ventricular Performance, Cardiovascular Anatomy and Histology, Fundamentals of Electrocardiography, Excitation-Contraction Coupling, Cardiac Electrophysiology: Membrane Phenomena, Myocardial Mechanics, Cardiac Energy Metabolism, Regulation of Cardiac Output, Determinants of Myocardial O_2 Consumption, Mechanics of Coronary Blood Flow, Exercise Physiology, The Lymphatic System, Regulation of Blood Volume, Humoral Regulation of the Circulation, and Neural Regulation of the Circulation.

Integrated Micro and Nanotechnology Sensory Systems Dr. Orly Yadid-Pecht	ENEL 691	Integrated circuits for sensing. The physical process of sensing photons and ions. The circuitry of signal amplification. Considerations for integrated circuit implementation. Solid state sensors and development in CMOS technology. Analog to Digital conversion in sensory arrays. Technology scaling and impact. Low voltage and implications regarding signal processing. Other types of sensors such as pH sensing. Mems technology and applications. MEMS based biopsy. Integrated Light sources. System examples.
Medical Imaging Techniques Dr. Samuel Pichardo	MDSC 689.01 (H) / ENEL 619.01 (H)	Introduction to the theory and practical applications of medical imaging. Specific course provides an overview of modern diagnostic imaging techniques.
Biomedical Systems and Applications Dr. M. P. Mintchev	ENEL 623 (H)	Instruction to biomedical instrumentation. The four elements of an electronic monitoring system. Errors and error handling. Instrument modelling. Sensors: Basic Concepts. Conversion of different processes into voltages or currents. Introduction to biomedical amplifiers. Ideal op amp. The concept of patient protection. Differential and instrumentation amplifiers. Non-I dealities in biomedical amplifiers. Noise and noise sources. Error analysis. Offsets and offset compensation. Power supplies for instrumentation circuits. Frequency characteristics of biomedical amplifiers. Frequency conditioning circuits. Active filters. Isolation amplifiers and details on patient protection. Analog-to-Digital conversion. Basic principles and conversion errors. Nyquist theorem of discretization and antialiasing requirements. Multichannel data acquisition. Real-time requirements. Real-time digital conditioning of monitored biomedical signals. The concept of closed-loop real-time control of biomedical systems.
Optical Instrumentation Dr. Kartikeya Murari	ENEL 606 This course formerly ENEL 619.68	Course description: Introduction to optical instrumentation used in engineering and biomedical research. Instrument construction, operation and principle. Interpretation of data, performance limitations and noise. Current research trends. Topics: ray and wave optics, microscopy, light sources, photodetectors and imaging, optical fibers, spectroscopy. WED 16:00 – 18:45 - ST 125
Advanced Cell and Tissue Engineering Dr. Michael S. Kallos	ENCH 659 (H)	Check system for details or contact Chem and Petroleum Department Current challenges in tissue engineering. Review of cell biology and biochemistry followed by an exploration of cell and tissue function and dysfunction and strategies to repair or restore function by taking into account stem cell availability and activities, tissue microenvironments and mass transfer, and clinical delivery of therapies.

Wireless Networks Dr. Fapojuwo	ENEL 633 (H)	Overview of the components and architectural alternatives for wireless networks. Review of existing and proposed wireless network standards (e.g., Advanced Mobile Phone System – AMPS, Digital AMPS, Interim Standard 95 – IS95, Global System for Mobile Communications – GSM, Code Division Multiple Access 2000 – CDMA2000, Universal Mobile Telecommunications System – UMTS, etc.). Discussion of wireless network communication protocols including network access control protocols, routing, congestion and flow control protocols, mobility and resource management protocols. Modeling and analysis of wireless networks and performance in the context of voice, data and video services making use of mathematical and simulation techniques. Outline of current and future research challenges in wireless.
Advanced Continuum Mechanics Instructor: Salvatore Federico	ENME 653 (H)	Review of linear algebra: vector spaces, linear maps, tensors; affine spaces: coordinate systems and differential calculus; kinematics of continua: deformation and strain tensors, deformation and strain rates; balance equations: mass, linear momentum, angular momentum, energy; entropy inequality; stress tensors; stress rates; stress power and conjugated stress-strain pairs; constitutive theory: constitutive axioms, hyperelastic solids, perfect and Newtonian fluids.
Virtual Environments and Applications Dr. Yaoping Hu	ENEL 602	Introduction to virtual reality (VR) technologies; Characterization of virtual environments; hardware and software; user interfaces; 3D interaction; research trends. Applications: medicine, manufacturing, oil and gas reservoirs, the arts, and education. Antirequisite(s): Credit for Electrical Engineering 604 and 619.38 will not be allowed.
Fracture of Civil Eng Materials Dr. Nigel Shrive	ENCI 617	Cohesive strength; plasticity. Fracture mechanics in relation to structural steel, stress intensity, fracture toughness, energy release rate, LEFM, COD, J-Integral, R-Curve, fatigue. Compressive fracture of concrete, masonry and rocks; cracking patterns, fracture theories, damage models, test methods and effects.

WINTER 2021 – Approved by the BME Graduate Program		
COURSE TITLE / INSTRUCTOR (S)	**COURSE #**	**COURSE Description**
Biomedical Engg Core II Dr. John Bertram	**BMEN 604** **CORE COURSE**	NOTE: Mandatory Courses for BME Graduate Program Students Topics may include an introduction to a) research methodology, including experimental design and b) written research communication skills in biomedical engineering, and c) preparation and review of research proposals. Satisfactory completion of this course within one year of first registration will ensure that the Biomedical Engineering Graduate Program Research Proposal requirements are met.
Anatomy and Physiology Dr. John Bertram	BMEN 609 (H) Combined with BMEN 309 Undergrad Course	Advanced instruction on human skeletal structure, types of connective tissues, structure of joints, muscle and organ structure and function, cardiac physiology, blood properties and flow, introduction to autonomous nervous System, and disorders of the musculoskeletal system. Other topics will be covered dependent on the interests of the instructor and students
NEW MDSC 755, TB Scheduled Instructor: Dr. Signe Bray For more Information contact: slbray@ucalgary.ca	MDSC 755 Introduction to Scientific Programming	The goal of this introductory scientific computing course is to prepare graduate students to use computing tools in research. The course will cover fundamentals of computer science, including computer architecture, data types, types of computer programming languages, operators, branching/looping, syntax and semantics, basics of software design and testing. We will then consider how these concepts are implemented in three tools that are commonly used in the scientific community: MATLAB, R and Python. Lectures and assignments will focus on areas relevant to data reading, manipulation and analysis. Final projects will allow students to gain more depth in a chosen area. Course lectures will be held in a computer lab for hands-on learning.
NEW Dr. Svetlana Yanushkevich	ENEL 610 Biometric Technologies and System Design	Biometric systems, sensors and devices. Integration of biometric-based hardware and software. Biometric applications in healthcare and security access. Calendar Reference (choose as appropriate): http://www.ucalgary.ca/pubs/calendar/ Course pre-requisites: consent of instructor. Credit for both ENCM 509, ENEL 619.76 and ENEL 610 will not be allowed

Dr Derrick Rancourt Advanced Topics in Stem Cell Biology and Regenerative Medicine	VETM 702	The course will provide a comprehensive overview of stem cell biology in the context of embryonic development and adult tissue maintenance. Students will gain an appreciation for embryonic versus adult stem cells and how these pluripotent or multipotent cells may be utilized toward regenerative medicine (ie treatment of congenital defects, disease or injury). Individual lectures will cover embryonic stem cells, iPS cells, germline stem cells as well as various tissue-specific adult stem cells including nervous system, skin, intestine and connective tissues. Their roles in development, organ maintenance, regeneration and disease will be discussed. Students will also be introduced to the ethical and legal issues surrounding stem cell research and their potential clinical use. Finally, several lectures will also discuss current research focused on exploiting the body's endogenous regenerative potential as well as potential therapeutic applications (including stem cell transplantation and bioengineering) to enhance tissue regeneration following injury or disease.
Advanced Image Processing Dr. Nils Forkert Dr. Steven Boyd	BMEN 619.14 / MDSC 689.03	Development of computer-based methods to generate quantitative data from common three-dimensional medical imaging technologies. Applications for computed tomography, magnetic resonance imaging, and other imaging techniques. Students will be introduced to methods of image processing, visualization, and advanced algorithms to evaluate image data. Applications will be morphometic measurements, finite element methods to image data, and visualization methods. Efficient algorithm development is a goal. Students perform a project implementing quantitative imaging algorithms related to their field of research.
Cardiovascular Pathophysiology Dr. John V. Tyberg	MDSC 629.02 (H)	An introductory study of the major cardiovascular disease entities – ischemic heart disease, congestive heart failure, arrhythmias, cardiac hypertrophy, congenital heart disease, and shock -- recapitulating the principles presented in MDSC 629.01. (Not recommended for students having completed medical training.)
Advanced Magnetic Resonance Imaging Dr. Bradley Goodyear	MDSC 689.02 (H)	This course will provide an in-depth description of the phenomena underlying nuclear magnetic resonance (NMR) and how NMR is used in magnetic resonance imaging (MRI). Applications of NMR and MRI in modern medicine will also be discussed. The course will cover NMR physics using both classical and quantum mechanical descriptions, the physical principles of excitation and signal detection, and selected clinical and research applications of MR imaging in medicine. The course is aimed at graduate students with sufficient technical background in signal processing, complex variables, and Fourier theory. MR will be taught from a systems/signal processing perspective. Some knowledge of NMR physics is assumed and a background in medical imaging theory would be of benefit, both of which can be gained through MDSC689.01/ENEL619.01. Background in either engineering or physics would be appropriate.

Advanced Muscle Mechanics Dr. Walter Herzog	KNES 663 (H) ENME 663 (H)	The aim of this class is to familiarize students with the current thinking on mechanisms of contraction in skeletal and cardiac muscles, muscle mechanical and functional properties, and to expose students to controversies in science through specific examples taken from the field of muscle mechanics MW 9-10:15
Virtual Environments and Applications Dr. Yaoping Hu	ENEL 602 (H)	Introduction to virtual reality (VR) technologies; Characterization of virtual environments; hardware and software; user interfaces; 3D interaction; research trends. Applications: medicine, manufacturing, oil and gas reservoirs, the arts, and education. Prerequisite: Objected-Oriented Programming C++
Theory and Applications of the Finite Element Method Dr. Neil Duncan	ENCI 653	Conceptual framework of the finite element method with emphasis on applications to structural analysis: shape functions, continuity at nodes, numerical integration, matrix assembly. Scope of the method, use of basic equations of elasticity, displacement (stiffness) method of analysis. Sources of error and poor performance; mesh sensitivity; element types, their selection and behaviour. Applications in structural analysis, heat conduction and other non-structural problems; use of available finite element programs.
Statistical Techniques in Kines Dr. Palacious-Derflingher	KNES 609	Basic concepts of statistical analysis as they apply to research methods used in various disciplines in kinesiology. This course may not be repeated for credit.
Medical Imaging Applications Course Coordinator: Dr. Catherine Lebel	MDSC 689.11 (H)	This course teaches research methods relevant to medical imaging. Lectures will cover basic statistical analysis and advanced statistics relevant to medical imaging analysis. Students will learn how to critically evaluate medical imaging literature. The class will overview basic image analysis techniques common to different modalities (e.g., assessing reproducibility), and provide a basic introduction to analysis techniques relevant to multiple imaging disciplines (e.g., machine learning, finite element analysis).
Advanced DSP processor Architecture Instructor: M. Smith	ENEL/ENCM 653 (H) (formerly ENEL 619.23)	Lectures and laboratories are intended to enable students to gain sufficient experience to develop a medical product based around advanced embedded systems running on highly parallel processors (suitable for image processing). Testing is an important part of the course. This is a

		graduate level variant of ENCM515 and students are encouraged to make the course project relevant to their thesis.
Micro/Nano system Design, Fabrication and Integration Dr. Colin Dalton	ENEL 619.50	Micro/nano system design, fabrication and integration' should be added to the list. Basic course details are 'Students taking this course will gain a solid grounding in the techniques and technologies associated with the design, development, fabrication and integration of micro/nano systems for application in many fields, including lab-on-a-chip, microfluidics, biomedical engineering and other areas'
Biometric Tech & Sys Design Dr. Yanushkevich	ENEL 619.76 / (BMEN 619.16)	The course covers biometric technologies that are used to process biometrics (human physiological and behavioural traits such as voice, facial images and expressions, gait, body temperature patterns, gestures) using interdisciplinary approaches: methods and techniques from signals and systems, information system design, signal and image processing, statistics and pattern recognition, Bayesian data analysis and risk estimations. It focuses on design of biometric systems, sensors and devices, and integration of biometric-based hardware and software for the applications in healthcare and security access. Statistical pattern recognition using palm biometrics for identification of users of heath care facility. The course will be evaluated via midterm and final examination, as well as the projects. Examples of the projects include "Facial biometrics for user identification using Deep Learning", "Facial expression and pain (via facial expression) recognition using Support Vector machines", and "Gesture–controlled human-machine interface using Microsoft Kinect for touchless screen browsing for health care providers".