UNIVERSITY OF CALGARY COURSE LEGEND	
ENCI = Civil Engineering Department	ENME = Mechanical Engineering Department
ENCH/ENPE = Chemical & Petro Engineering Department	ENEL = Electrical and Computer Engineering Dept
MDSC – Cumming School of Medicine	KNES = Faculty of Kinesiology
ENGO = Geomatics Engineering Department	BMEN 6XX = BME Graduate Program
BIOL = Biological Sciences / Faculty of Science	BMEN 619.XX – Special Topic Courses

STUDENTS/SUPERVISORS:

It is important that if a course is not on this list, students are to obtain an **official course outline** and submit to the BME Graduate Program office, bmegrad@ucalgary.ca.

Courses may be approved on either

1. "case by case" based (individual student) or
2. may receive "blanket" approval and is added to this document. Not all courses approved automatically get listed here.

Consideration criteria as follows:

- Half course equivalent (3.00 units) - Weight of course matters
- Biomedical engineering/science in nature and in support of your BME Graduate Degree
- Syllabus (course outline) providing the overall design of the course goals, evaluation of student(s) (**grading schematics, assignments, projects**) etc

NON-Science Courses:

Although the BME Graduate Program strongly encourage our students to take non-science courses, seminars, workshop etc to enhance their research and knowledge base (ie entrepreneurship courses ENTI, ENGG 683) however non-science type courses do not count towards BME Graduate Program degree requirements.

AUDIT

Students can audit courses. Please note that auditing a course will not count towards your degree course requirements.

Special Topic Courses

(**aka** Reading Course/Directed Study Course) – **BMEN 619.XX**

This is when a supervisor requests a special course to be created and the content is specific to the student's BME research. Requests must be made by the BME Faculty Supervisor by initially contacting the BME Graduate Program Office, bmegrad@ucalgary.ca a minimum of 4 weeks prior to a year/term.

MDSC 755 – Please ensure you provide the BME Graduate Program Office with an official course outline as MDSC 755 is a generic course code name for several different Directed Study courses and subjects available to students. Please seek approval prior to registration.

REMINDER

This list is a courtesy to students in our program providing a list of most common BME Technical Electives. Students are advised to search the registration system. Courses on this list are not guaranteed to be offered every year/term. Students are to connect directly with the instructor listed here for further details.

Every year, courses can be cancelled for many reasons and/or new courses created involving many faculties and departments across campus that our BME Graduate Program are connected to. This list serves as a starting point for students and is only a guide. Students can discuss their degree course requirements with their supervisor. If student and/or supervisor have any questions, they can email the BME Graduate Program Office. bmegrad@ucalgary.ca

Last Updated: NOV 2021

FALL 2021

Biomedical Engg Foundations 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).
Biomedical Engg Core I 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.
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	**I**ntroductory 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 Herzog Dr. Brent Edwards	KNES 664 (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. 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.
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.
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.
Theory and Applications of the Finite Element Method Dr. Rahil Khoshnazar	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.
Application of 3D Rigid Body Mechanics in Biomechancis Dr. Janet Ronsky	ENME 683	Applications of 3D motion analysis and rigid body mechanics to musculoskeletal system locomotion, and movement. Experimental, theoretical and numerical methods for optical motion imaging, 3D analysis of joint kinematics and kinetics, joint angle representations, prediction of joint forces, data analysis and filtering, error propagation, inverse and forward dynamics approaches and applications to clinical and orthopaedic engineering.
Advanced Data Analytics Dr. Ethan MacDonald	ENSF 619.01	Research skills course designed to expand knowledge with supercomputing clusters, numerical methods, and analyses. Introduction to version control and source management. Data curation, management, and compliance. Using schedulers for parallelization. Benchmarking computational requirements. Machine learning and numerical processing for challenging data analytics problems. Reducing high dimensionality data for interpretation. Making graphics from data.

Advanced Topics in Image Analysis and Machine Learning Dr. Roberto Medieros de Souza	ENSF 619.01	This course focuses on advanced machine learning and image analysis techniques. The course will cover the following topics: graph-based image representation, image segmentation, state-of-the-art methods on ImageNet, self-supervised learning, domain adaptation, adversarial models, and AutoML . A special emphasis will be given to recent cutting-edge techniques. The course will be hands-on.
Search registration system for courses listed under this course name	MDSC 755	As per Dr. Tara Beattie, all courses that fall under the umbrella of MDSC 755 are all graded and equivalent to half course / GFC hours

WINTER 2022

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
Biometric Technologies and System Design Dr. Svetlana Yanushkevich	ENEL 610	Biometric systems, sensors and devices. Integration of biometric-based hardware and software. Biometric applications in healthcare and security access.
Advanced Topics in Stem Cell Biology and Regenerative Medicine Dr Derrick Rancourt	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.

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
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. Robert Rose	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)	An in-depth study of the principles of magnetic resonance imaging (MRI), recent technological advances in MRI, and how MRI is used to study brain structure and function in combination with other imaging technologies. Individuals will gain practical experience with MRI data and current analysis techniques.
Advanced Muscle Mechanics Dr. Walter Herzog **OFFERED Every 2nd year. **NEXT Offer Winter 2023	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.
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++
Medical Imaging Applications 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 ENCM 515 and students are encouraged to make the course project relevant to their thesis.
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.
Micro/Nano System Design, Fabrication and Integration Dr. Colin Dalton	ENEL 616	Techniques for the fabrication of micro/nano systems, including ultra-thin films and multilayers. Industry-standard metrology techniques and technologies for characterization of the structure, chemistry and properties of micro/nano materials and devices. Fundamental fabrication technologies including bulk micromachining, surface micromachining and commercial methods. Bonding and packaging issues related to the micro/nano scale. This course may not be repeated for credit
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. 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".
Data Mining & Machine Learning Winter Term ONLY with Dr. Roberto Medeiros de Souza as instructor	ENEL 645	This course is a hands-on course on Deep Learning (DL), which is a significant topic within machine learning. This course will give an overview of the historical context that allowed DL to flourish. It will cover different types of neural networks, how to train, and deploy them in different problems, such as image classification, image segmentation, and signal denoising. The neural network types that will be covered are fully connected networks, convolutional neural networks, fully convolutional neural networks, auto-encoders, recurrent neural networks, and others. Special emphasis will be given to popular network architectures like U-nets, ResNets, Inception, and VGG. The course will cover how to fine-tune pre-trained models to achieve state-of-the-art results in relevant applications. This course will also give a brief introduction to generative models, self- supervised learning and an overview of current new trends in DL.

Principles for Neural Science for Engineers Dr. Kartik Murari	BMEN 619.31	This course is an introduction to fundamental biophysics, physiology and anatomy of the central nervous system for engineers without an extensive background in biology. Specific topics may include ion channels, membrane potential, action potential, synaptic transmission and processing, neuroanatomy of the mammalian brain, neuromodulation and neurophysiological recording. The above concepts will be integrated in the context of the motor system. Readings will be assigned from textbook and research articles.
Search registration system for courses listed under this course name	MDSC 755	As per Dr. Tara Beattie, all courses that fall under the umbrella of MDSC 755 are all graded and equivalent to half course / GFC hours

SPRING 2021

Signal Transduction Dr. Roman Krawetz	BMEN 619.19	This course will explain how extracellular signals regulate cells and how do cells respond to these signals. Answers to these questions are critical for understanding the molecular pathways that control cell fate and function. This course, will examine how a number of signal transduction pathways influence cell functions such as: cell fate, gene transcription, protein translation, intracellular protein trafficking, cell proliferation and programmed cell death. The primary signal transduction pathways examined (but not limited to) include those mediated by: PI-3 kinase, Notch, TGFbeta, NF-kB, Wnt, and Ras.