

BIOMEDICAL ENGINEERING (B M E)

B M E 1 – COOPERATIVE EDUCATION PROGRAM

1 credit.

Work experience which combines classroom theory with practical knowledge of operations providing a background upon which to base a professional career in industry.

Requisites: Sophomore standing

Course Designation: Workplace - Workplace Experience Course

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Identify and respond appropriately to real-life engineering ethics cases relevant to co-op work Audience: Undergraduate

2. Synthesize and apply appropriate technical education to real world technical work Audience: Undergraduate

3. Communicate effectively in writing and speaking with a range of audiences in the workplace, including those without disciplinary expertise Audience: Undergraduate

4. Develop professional and transferable habits like time management skills, collaborative problem-solving skills, and research skills for learning new information Audience: Undergraduate

B M E 200 – BIOMEDICAL ENGINEERING DESIGN

2 credits.

Collaborate with students in B M E 300 on a client-centered biomedical engineering design project to learn concept generation, product analysis, specifications, evaluation, regulation, and ethics.

Requisites: Sophomore standing and declared in Biomedical Engineering

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies Audience: Undergraduate

B M E 201 – BIOMEDICAL ENGINEERING DESIGN AND FUNDAMENTALS

3 credits.

Fundamentals of biomedical engineering and principles of design including the design process, standards, documentation, inclusion in design and research methods. Hands-on skills including electronics, programming, computer-aided design, machining, safety training, microscopy, cell and tissue engineering principles and fabrication of physical prototypes.

Requisites: B M E 200

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies Audience: Undergraduate

B M E 300 – BIOMEDICAL ENGINEERING DESIGN AND LEADERSHIP

3 credits.

Work on a client-centered biomedical engineering design project to learn leadership styles, concept generation, product analysis, specifications, evaluation, regulation, and ethics. Provide leadership and mentorship to students in B M E 200.

Requisites: B M E 201

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies Audience: Undergraduate

B M E 301 – BIOMEDICAL ENGINEERING DESIGN AND COMMUNICATION

3 credits.

Technical communication for biomedical engineering practice applied to real-world, client-based projects including research methods, documentation, preparing and critiquing reports, ethical problem solving, diversity and inclusion, presenting, and professional development.

Requisites: Satisfied Communications A requirement and B M E 201

Course Designation: Gen Ed - Communication Part B

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies Audience: Undergraduate

B M E 310 – BIOINSTRUMENTATION

3 credits.

Bioinstrumentation covering clinical and research measurements.

Laboratory experiments complement the lectures.

Requisites: (CHEM 104, 109, or 116), MATH 222, and (PHYSICS 202, 208, or 248), or member of Engineering Guest Students

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Solve mathematical problems for electrical and electronic circuits Audience: Undergraduate

2. Employ simulation tools to analyze electrical and electronic circuits Audience: Undergraduate

3. Design and build basic instrumentation system for measuring physiological and biological signals Audience: Undergraduate

4. Program a microcontroller to acquire and process physiological and biological signals Audience: Undergraduate

5. Perform experiments using the instrumentation system, analyze data and draw conclusions Audience: Undergraduate

B M E 315 – BIOMECHANICS

3 credits.

An introduction to the mechanical behavior of biological tissues and systems. Specific topics include: structure and function of biological tissues, mechanical properties of biological tissues, and analysis of specific tissues (i.e. bone, muscle, and soft connective tissues).

Requisites: (E M A 303 or M E 306), or member of Engineering Guest Students

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Apply mechanical equilibrium analyses to compute forces acting on tissues, organs and structures within the human body Audience: Undergraduate

2. Examine mechanical stress and deformation associated with the loading of biological tissues Audience: Undergraduate

3. Analyze, interpret and present data collected during experiments in biomechanics Audience: Undergraduate

4. Describe the relevance of mechanics for investigating biological systems at scales ranging from cellular to the whole body Audience: Undergraduate

B M E 325 – APPLIED STATISTICS FOR BIOMEDICAL ENGINEERS

3 credits.

Learn and apply the fundamentals of descriptive and inferential statistics to analyze data and present the results in appropriate graphical formats. Emphasis will be on applications commonly encountered in biomedical engineering including t-tests, linear regression, analysis of variance, diagnostic tests, ROC curves, and methods for graphing and presenting data. Examples and practice problems will be drawn from biomedical research. Learn how to analyze data and interpret statistical analysis presented in research papers, and will get practical hands-on experience implementing these tools during class in a computer lab setting.

Requisites: Declared in Biomedical Engineering and MATH 222

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. interpret statistics that are presented and recognize statistical evidence that supports a conclusion Audience: Undergraduate

2. apply descriptive statistical analysis to data Audience: Undergraduate

3. make inferences based on sampled data (test a hypothesis) Audience: Undergraduate

4. present data and statistical analysis in appropriate graphical format Audience: Undergraduate

B M E 330 – ENGINEERING PRINCIPLES OF MOLECULES, CELLS, AND TISSUES

4 credits.

Introduction to the fundamental principles of kinetics and transport that are relevant for the analysis of biological systems. Topics covered include concepts of reaction rate, stoichiometry, equilibrium, momentum/mass transport, and the interaction between transport and kinetics in biological systems.

Requisites: (E M A 201, PHYSICS 201, 207, or 247), (MATH 319, 320, or 375) and (CHEM 104, 109, or 116), or member of Engineering Guest Students

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Assess the relationship between system variables based on dimensional homogeneity and dimensional analysis Audience: Undergraduate

2. Convert a reaction system into a series of kinetic equations Audience: Undergraduate

3. Recognize the parallels between different transport mechanisms Audience: Undergraduate

4. Analyze kinetic and transport equations to determine dynamic and steady state behavior Audience: Undergraduate

5. Evaluate how the physical principles of kinetics and transport constrain living organisms and impact the design and interpretation of biological experiments Audience: Undergraduate

B M E 389 – HONORS IN RESEARCH

1-3 credits.

Undergraduate honors research projects supervised by faculty members.

Requisites: Consent of instructor

Course Designation: Honors – Honors Only Courses (H)

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Conduct and report on independent biomedical engineering research Audience: Undergraduate

2. Formulate hypotheses into experimental methods Audience: Undergraduate

B M E 399 – INDEPENDENT STUDY

1-3 credits.

Directed study projects as arranged with instructor.

Requisites: Consent of instructor

Course Designation: Level – Advanced

L&S Credit – Counts as Liberal Arts and Science credit in L&S

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Conduct and report on independent biomedical engineering research Audience: Undergraduate

B M E 400 – CAPSTONE DESIGN COURSE IN BIOMEDICAL ENGINEERING

3 credits.

Applies classroom study and prior design course experiences for senior teams to solve a directed client-based biomedical engineering design project.

Requisites: (B M E 300 or B M E 301) and (B M E 310, 315, or PHM SCI/ B M E 430)

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies Audience: Undergraduate

B M E 402 – BIOMEDICAL ENGINEERING CAPSTONE DESIGN II

3 credits.

Work in a team to evaluate, refine, document and present the client-centered biomedical engineering design started in B M E 400.

Requisites: B M E 400

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies Audience: Undergraduate

B M E/M E 414 – ORTHOPAEDIC BIOMECHANICS - DESIGN OF ORTHOPAEDIC IMPLANTS

3 credits.

Apply the design process for orthopaedic implants (total joint replacements). Topics include: library skills; joint anatomy; tissue properties; surgical approach; joint loading; implants materials; preclinical testing and analysis.

Requisites: Senior standing and (M E 306 or E M A 303), or graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E/M E 415 – BIOMECHANICS OF HUMAN MOVEMENT

3 credits.

An overview of experimental and modeling techniques used to study human movement. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulation and imaging based biomechanics. Homework and laboratory activities emphasize applications of movement biomechanics in orthopedics and rehabilitation.

Requisites: B M E 315 and M E 340, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/PHM SCI 430 – BIOLOGICAL INTERACTIONS WITH MATERIALS

3 credits.

Addresses the range of materials currently being utilized for various biomedical applications, the biological systems governing biomaterial applications, analytical techniques pertinent to biomaterial evaluation, and selected major medical applications in which biomaterials play an important role.

Requisites: (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 383) and (CHEM 341 or 343)

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/E C E 462 – MEDICAL INSTRUMENTATION

3 credits.

Design and application of electrodes, biopotential amplifiers, biosensors, therapeutic devices. Medical imaging. Electrical safety. Measurement of ventilation, blood pressure and flow.

Requisites: E C E 340, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E/E C E 463 – COMPUTERS IN MEDICINE

3 credits.

Study of microprocessor-based medical instrumentation. Emphasis on real-time analysis of electrocardiograms. Labs and programming project involve design of biomedical digital signal processing algorithms. Knowledge of computer programming language like C, C++ or Java, strongly encouraged.

Requisites: E C E 330 and (COMP SCI 200, 220, 300, 301, or placement into COMP SCI 300), graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E 489 – HONORS IN RESEARCH

1-3 credits.

Biomedical engineering undergraduate honors research projects supervised by faculty members.

Requisites: Consent of instructor

Course Designation: Honors - Honors Only Courses (H)

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Conduct and report on independent biomedical engineering research Audience: Undergraduate

2. Formulate hypotheses into experimental methods Audience: Undergraduate

3. Prepare and defend experimental results and conclusions Audience: Undergraduate

B M E/H ONCOL/MED PHYS/PHYSICS 501 – RADIATION PHYSICS AND DOSIMETRY

3 credits.

Interactions and energy deposition by ionizing radiation in matter; concepts, quantities and units in radiological physics; principles and methods of radiation dosimetry.

Requisites: (PHYSICS 323, 449 and MATH 320) or graduate/professional standing or declared in Medical Physics VISP

Course Designation: Level - Advanced

L&S Credit - Counts as Liberal Arts and Science credit in L&S

Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E/M E 505 – BIOFLUIDICS

3 credits.

Introduction to the physics of biological fluid flow with an emphasis on the cardiovascular system including blood rheology, pulsatile flow, wave travel, and topics relevant to blood flow measurement and biomedical device design.

Requisites: B M E 330, CBE 320, M E 363, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E 510 – INTRODUCTION TO TISSUE ENGINEERING

3 credits.

Overview of tissue engineering, including discussion of cell sources, cell-material interactions, tailoring biomaterials, methods of culture and characterization of engineering tissues, ethical issues, concluding with case studies of specific types of tissue engineering. Optional laboratory exercises offered throughout semester.

Requisites: B M E/PHM SCI 430, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Identify the experimental assay that is appropriate to characterize a particular cellular behavior Audience: Both Grad Undergrad

2. Describe how to tailor mechanical properties, cell-material interactions, growth factor/gene delivery, and bioreactor conditions to match the needs of a biological system Audience: Both Grad Undergrad

3. Critically evaluate tissue engineering approaches Audience: Both Grad Undergrad

4. Assess a biological system and develop a tissue engineering strategy Audience: Both Grad Undergrad

5. Summarize and synthesize recent tissue engineering related research from various resources Audience: Graduate

B M E 511 – TISSUE ENGINEERING LABORATORY

1 credit.

Tissue engineering refers to the generation of biological substitutes to restore, maintain, or improve tissue function. Laboratory techniques are multi-disciplinary, from basic biological sciences, engineering, and biotechnology. Engineering approaches and analysis will be applied to these techniques.

Requisites: B M E 510 or concurrent enrollment, or graduate/professional standing

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Identify and describe the biology of, growth conditions for and laboratory equipment used in tissue culture Audience: Undergraduate

2. Design and conduct laboratory experiments, including making measurements and interpreting experimental data from living systems Audience: Undergraduate

3. Apply knowledge of advanced mathematics and statistical analysis to evaluate scientific outcomes Audience: Undergraduate

4. Communicate scientific findings from experimental results effectively Audience: Undergraduate

B M E/M E 516 – FINITE ELEMENTS FOR BIOLOGICAL AND OTHER SOFT MATERIALS

3 credits.

Finite element modeling of soft materials, with an emphasis on biological tissues. Basics of the finite element method, verification and validation methods, and selection of constitutive models. Emphasis on finite element modeling for materials that are generally nonlinear, and that generally undergo large deformation.

Requisites: (M E 306 or E M A 303), graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E 517 – BIOLOGY IN ENGINEERING SEMINAR

1 credit.

Current topics at the interface of biology and engineering with special emphasis on the ways in which engineers have contributed to knowledge and advances in biology.

Requisites: (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 381), graduate/professional standing, or member of Engineering Guest Students

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Identify and describe a wide variety of engineering approaches that have advanced our understanding of biology Audience: Undergraduate

2. Assimilate presented topics with relevant literature into writing Audience: Undergraduate

B M E 520 – STEM CELL BIOENGINEERING

3 credits.

Covers engineering approaches that are used to understand and manipulate stem cells. Concepts covered include: introduction to stem cell biology, quantitative modeling of stem cell signaling, methods to engineer the stem cell microenvironment, and the role of stem cells in tissue development and regeneration.

Requisites: (MATH 319 or 320), (ZOOLOGY 470, 570, or BIOCORE 383), and (CHEM 341 or 343), graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Describe the historical development and current state of stem cell engineering Audience: Both Grad Undergrad

2. Model stem cell signaling Audience: Both Grad Undergrad

3. Characterize the technical features and functions of stem cell therapy Audience: Both Grad Undergrad

4. Evaluate stem cell-based tissue development and regeneration Audience: Both Grad Undergrad

5. Demonstrate higher-order synthesis and analysis to address a current problem in stem cell bioengineering Audience: Graduate

B M E/MED PHYS 535 – INTRODUCTION TO ENERGY-TISSUE INTERACTIONS

3 credits.

Explore physical interactions between thermal, electromagnetic and acoustic energies and biological tissues with emphasis on therapeutic medical applications.

Requisites: PHYSICS 202, 208, 248, or PHYSICS/MED PHYS 265, or graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Derive and solve bioheat transfer problems relevant to therapeutic hyperthermia and hypothermia Audience: Both Grad Undergrad

2. Explain changes at the tissue and cellular levels during thermal therapies Audience: Both Grad Undergrad

3. Analyze technologies that apply electromagnetic and acoustic energy to tissue Audience: Both Grad Undergrad

4. Discuss medical applications and regulatory guidelines/requirements involving energy-tissue interactions Audience: Both Grad Undergrad

5. Demonstrate an advanced ability to synthesize recent literature, formulate technical problems, and describe plausible solutions Audience: Graduate

B M E 545 – ENGINEERING EXTRACELLULAR MATRICES

3 credits.

Overview of the structure, function and biophysical properties of extracellular matrix (ECM) proteins, followed by discussion of how control or manipulation of ECM protein expression and distribution impacts on cell and tissue function, concluding with impacts of engineering ECM for regenerative medicine.

Requisites: B M E/PHM SCI 430, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Describe the structure and function of individual ECM components and their relevance to physiological and pathophysiological processes Audience: Both Grad Undergrad

2. Apply biological knowledge of the ECM to inform the manipulation, mimicking, or engineering of ECM-based systems Audience: Both Grad Undergrad

3. Critically evaluate ECM engineering approaches Audience: Both Grad Undergrad

4. Apply advanced knowledge of bioconjugate chemistry to design dynamic scaffold platforms Audience: Graduate

B M E 550 – INTRODUCTION TO BIOLOGICAL AND MEDICAL MICROSYSTEMS

3 credits.

Introduction to the field of MEMS (Micro-Electro-Mechanical-Systems), as it applies to biology and medicine. Topics will cover methodology of traditional MEMS devices, how they can be incorporated with biological systems, and methods for micro-structuring biological materials.

Requisites: B M E 310 and (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 383), graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Identify prominent materials and their properties commonly used in fabrication of biomedical microdevices Audience: Both Grad Undergrad

2. Analyze and implement microfabrication techniques for patterning, lithography, etching and deposition Audience: Both Grad Undergrad

3. Understand and design fabrication processes with appropriate fabrication tools for biomedical microdevices Audience: Both Grad Undergrad

4. Describe the principles underlying the interface between biological samples and different microdevices Audience: Both Grad Undergrad

5. Analyze, demonstrate, and communicate recent scientific literature in the field of biomedical microdevices Audience: Graduate

B M E 556 – SYSTEMS BIOLOGY: MAMMALIAN SIGNALING NETWORKS

3 credits.

Introduction to the experimental and mathematical modeling techniques used in systems biology through lectures and critical analyses of relevant publications with a primary focus on gene/protein networks and mammalian systems.

Requisites: (MATH 319, 320, or 375), (B M E 510, ZOOLOGY 470, 570, PSYCH/ZOOLOGY 523, or BIOCORE 383) and Junior Standing, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2022

Learning Outcomes: 1. Describe the structure and function of individual extracellular matrix (ECM) components and their relevance to physiological and pathophysiological processes Audience: Both Grad Undergrad

2. Apply biological knowledge of the ECM to inform the manipulation, mimicking, or engineering of ECM-based systems Audience: Both Grad Undergrad

3. Critically evaluate ECM engineering approaches Audience: Both Grad Undergrad

4. Apply advanced knowledge of bioconjugate chemistry to design dynamic scaffold platforms Audience: Graduate

B M E/CBE 560 – BIOCHEMICAL ENGINEERING

3 credits.

Properties of biological molecules; enzyme kinetics, enzyme reactors, and enzyme engineering; metabolic engineering; microbial growth kinetics; bioreactor design; bioseparations.

Requisites: Junior standing and (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 383), graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/I SY E 564 – OCCUPATIONAL ERGONOMICS AND BIOMECHANICS

3 credits.

Introduces engineers how to design manufacturing and industrial operations in which people play a significant role, so that human capabilities are maximized, physical stress is minimized, and workload is optimized. Examples and topics emphasize industrial applications.

Requisites: PSYCH/I SY E 349 or B M E 315, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Evaluate jobs, equipment, tools, products, and environments, in which people play a significant role, for health and safety hazards and the risk of injuries and illnesses Audience: Both Grad Undergrad

2. Devise how to reduce or eliminate physical stresses and the risk of injuries and illnesses in jobs, equipment, tools, products, and environments Audience: Both Grad Undergrad

3. Design jobs, workspaces and products for a diverse work population, to accommodate the variability of human dimensions strength, endurance, and physical capacity to do work Audience: Both Grad Undergrad

4. Design jobs equipment, tools, products, and environments so that human capabilities are maximized, physical stress is minimized, and workload is optimized Audience: Both Grad Undergrad

5. Identify fundamental physiological principles and biomechanical theories that are germane to the evaluation, design and reduction or elimination of stresses and strain in jobs, equipment, tools, products, and environments Audience: Graduate

B M E/MED PHYS 566 – PHYSICS OF RADIOTHERAPY

3 credits.

Ionizing radiation use in radiation therapy to cause controlled biological effects in cancer patients. Physics of the interaction of the various radiation modalities with body-equivalent materials, and physical aspects of clinical applications.

Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/MED PHYS 567 – THE PHYSICS OF DIAGNOSTIC RADIOLOGY

4 credits.

Physics of x-ray diagnostic procedures and equipment, radiation safety, general imaging considerations; lecture and lab.

Requisites: MATH 234 and (PHYSICS 241 or 249) or graduate/professional standing

Course Designation: Breadth - Biological Sci. Counts toward the Natural Sci req

Level - Intermediate

L&S Credit - Counts as Liberal Arts and Science credit in L&S

Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2018

B M E/MED PHYS 568 – MAGNETIC RESONANCE IMAGING (MRI)

2 credits.

Core course covering the physics associated with magnetic resonance imaging emphasizing techniques employed in medical diagnostic imaging. Major MRI topics include: physics of MR, pulse sequences, hardware, imaging techniques, artifacts, and clinical applications. At the completion of this course, students should have an understanding of the technical and scientific details of modern magnetic resonance imaging and its use in diagnosing disease. Graduate students who have not taken MATH 222 and PHYSICS 202 at UW-Madison must have the equivalent coursework in order to be successful in this course.

Requisites: Graduate/professional standing or (MATH 222 and PHYSICS 202, 208, 241, 244, 248 or 249)

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2022

Learning Outcomes: 1. Identify the mechanisms in which nuclear magnetic resonance harnessed for imaging Audience: Both Grad Undergrad

2. Differentiate the different MRI sequences used and the appearance of disease aspects in each of these sequences Audience: Both Grad Undergrad

3. Evaluate potential biological effects of imaging on patients and effects of patients on imaging Audience: Both Grad Undergrad

4. Contextualize the acquired knowledge to formulate research questions to solve specific clinical needs Audience: Graduate

B M E/MED PHYS 573 – MATHEMATICAL METHODS IN MEDICAL PHYSICS

3 credits.

Mathematical fundamentals required for medical physics and biomedical applications, including signal analysis and mathematical optimization.

Requisites: (MATH 234 and 319), (MATH 234 and 320), or MATH 376 and (PHYSICS 202 or 208), graduate/professional standing, or declared in Medical Physics VISP

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E/MED PHYS 574 – DATA SCIENCE IN MEDICAL PHYSICS

3 credits.

Concepts and principles of statistics and machine learning for medical physics-related research problems. Topics covered include probability and independence, discrete and continuous random variables and statistical distributions, random sampling and central limit theorem, inference for means, variances, proportions, moment generating functions, maximum likelihood, hypothesis testing, ANOVA, linear regression, correlation and basic design of experiments with application to quality assurance, reliability, and reproducibility.

Requisites: (PHYSICS/B M E/H ONCOL/MED PHYS 501 and B M E/MED PHYS 573) or (STAT/MATH 309 or 431) or graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/MED PHYS 575 – DIAGNOSTIC ULTRASOUND IMAGING

2 credits.

Propagation of ultrasonic waves in biological tissues; principles of ultrasonic measuring and imaging instrumentation; design and use of currently available tools for performance evaluation of diagnostic instrumentation; biological effects of ultrasound.

Requisites: Graduate/professional standing or (MATH 234, 319, or 320 and PHYSICS 202 or 208)

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2019

Learning Outcomes: 1. Explain principles underlying ultrasound propagation and biological effects of ultrasound. Audience: Both Grad Undergrad

2. Apply knowledge of clinical uses and limitations/artifacts of ultrasound imaging. Audience: Both Grad Undergrad

3. Recall the technical details of modern medical ultrasound devices and methods to measure acoustic parameters. Audience: Both Grad Undergrad

4. Utilize and integrate ultrasound imaging approaches for diagnostic and therapeutic research and clinical applications. Audience: Graduate

B M E/MED PHYS 578 – NON-IONIZING DIAGNOSTIC IMAGING

4 credits.

Covers the physics associated with magnetic resonance imaging and diagnostic ultrasound emphasizing techniques employed in medical diagnostic imaging. Major MRI topics include: physics of MR, pulse sequences, hardware, imaging techniques, artifacts, and spectroscopic localization. Ultrasound based topics covered include: propagation of ultrasonic waves in biological tissues, principles of ultrasonic measuring and imaging instrumentation, design and use of currently available tools for performance evaluation of diagnostic instrumentation, and biological effects of ultrasound. Gain an understanding of the technical and scientific details of modern non-ionizing medical magnetic resonance and ultrasound devices and their use in diagnosing disease.

Requisites: MATH 234, (MATH 319 or 320) and (PHYSICS 202, 208, 241 or 248), or graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/MED PHYS 580 – THE PHYSICS OF MEDICAL IMAGING WITH IONIZING RADIATION

4 credits.

Concepts and principles on the physics of medical imaging systems that form images using high energy photons are presented. Such systems are divided into two categories: (1) those based on the transmission of x-rays through the human body, including radiography, mammography, fluoroscopy, and computed tomography (CT), and (2) those based on the emission of gamma rays or annihilation radiation following radioactive decay of an internal radiolabeled molecule, including the gamma camera, single photon emission tomography (SPECT), and positron emission tomography (PET) and PET hybrid imaging systems. Emphasis is placed on understanding how physics, system design, and imaging technique determine image performance metrics such as contrast, signal-to-noise ratio, and spatial resolution. Clinical applications and radiation safety concepts are detailed for the different types of imaging systems.

Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501 and MED PHYS/B M E 573

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E 601 – SPECIAL TOPICS IN BIOMEDICAL ENGINEERING

1-3 credits.

Directed study projects as arranged with instructor.

Requisites: None

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomedical engineering Audience: Undergraduate

2. Apply key theories, concepts, and methods in biomedical engineering, using appropriate tools, processes, and/or software Audience: Undergraduate

B M E 602 – SPECIAL TOPICS IN BIOMEDICAL ENGINEERING

1-3 credits.

Special topics in biomedical engineering for graduate students or both graduate and undergraduate students together.

Requisites: None

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Fall 2023

Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomedical engineering Audience: Both Grad Undergrad

2. Apply key theories, concepts, and methods in biomedical engineering, using appropriate tools, processes, and/or software Audience: Both Grad Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomedical engineering Audience: Graduate

B M E 603 – SPECIAL TOPICS IN BIOINSTRUMENTATION AND MEDICAL DEVICES

1-3 credits.

Various special topics in bioinstrumentation and medical devices.

Requisites: None

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

B M E 604 – SPECIAL TOPICS IN BIOMEDICAL IMAGING AND OPTICS

1-3 credits.

Various special topics in biomedical imaging and optics.

Requisites: None

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomedical imaging and optics Audience: Both Grad Undergrad

2. Apply key theories, concepts, and methods in biomedical imaging and optics, using appropriate tools, processes, and/or software Audience: Both Grad Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomedical imaging and optics Audience: Graduate

B M E/M E 605 – SPECIAL TOPICS IN BIOMECHANICS

1-3 credits.

Various special topics in biomechanics.

Requisites: None

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomechanics Audience: Both Grad Undergrad

2. Apply key theories, concepts, and methods in biomechanics, using appropriate tools, processes, and/or software Audience: Both Grad Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomechanics Audience: Graduate

B M E 606 – SPECIAL TOPICS IN BIOMATERIALS, CELLULAR AND TISSUE ENGINEERING

1-3 credits.

Various special topics in biomaterials, cellular and tissue engineering.

Requisites: None

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomaterials, cellular and tissue engineering Audience: Both Grad Undergrad

2. Apply key theories, concepts, and methods in biomaterials, cellular and tissue engineering, using appropriate tools, processes, and/or software Audience: Both Grad Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomaterials, cellular and tissue engineering Audience: Graduate

B M E/M E 615 – TISSUE MECHANICS

3 credits.

Focus on solid mechanics of prominent musculoskeletal and cardiovascular tissues. Their normal and pathological behaviors (stiffness, strength, relaxation, creep, adaptive remodeling, etc.) in response to physiologic loading will be examined and quantified.

Requisites: M E 306 or E M A 303, or graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E/MED PHYS/PHMCOL-M/PHYSICS/RADIOL 619 – MICROSCOPY OF LIFE

3 credits.

Survey of state of the art microscopic, cellular and molecular imaging techniques, beginning with subcellular microscopy and finishing with whole animal imaging.

Requisites: PHYSICS 104, 202, 208, or 248 or PHYSICS/MED PHYS 265

Course Designation: Level - Intermediate

L&S Credit - Counts as Liberal Arts and Science credit in L&S

Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E 640 – MEDICAL DEVICES ECOSYSTEM: THE PATH TO PRODUCT

3 credits.

Development of medical devices for therapeutic or diagnostic purposes. Gap analysis, market analysis, reimbursement/distribution, regulatory approval, and manufacturing/supply chain development. Refinement and presentation of design ideas and corporate strategy within a team setting. Case studies of device design/manufacture including supply chain, intellectual property, pre-clinical testing, U.S. and European regulatory pathways and clinical trial design.

Requisites: B M E 402 or concurrent enrollment, graduate/professional standing, or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Develop an evolving competitive landscape analysis Audience: Both Grad Undergrad

2. Identify common issues in manufacturing/supply chain Audience: Both Grad Undergrad

3. Describe key aspects of clinical trial design Audience: Both Grad Undergrad

4. Discuss intellectual property both In theory and in practice Audience: Both Grad Undergrad

5. Articulate the differences between regulatory pathways in Europe and the United States Audience: Graduate

6. Define key aspects of pre-clinical testing, including Quality Systems, Good Laboratory Practices, and Good Manufacturing Practices Audience: Graduate

B M E 651 – BIOPHOTONICS LABORATORY

3 credits.

Learn and apply the fundamentals of optical imaging, microscopy and instrumentation via practical hands-on training with a specific emphasis on the life-sciences applications. Topics include constructing imaging systems using fundamental optical tools and instruments, illumination and aberrations, microscopy techniques, resolution and contrast measurement, optical spectroscopy, nanophotonics, bioimaging and biosensing.

Requisites: PHYSICS 202, 208, 248, MED PHYS/PHYSICS 265, E C E 320, 434, or graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Identify and use optical tools and instruments and construct optical imaging systems Audience: Both Grad Undergrad

2. Measure optical resolution and summarize parameters, such as optical aberrations, illumination and collecting optical system settings, that affect resolution in optical imaging Audience: Both Grad Undergrad

3. Implement Kohler illumination, identify conjugate planes and illustrate Abbe theory of image formation on a hands-on optical hardware Audience: Both Grad Undergrad

4. Measure contrast in different microscopy techniques and identify parameters that contribute to signal-to-background Audience: Both Grad Undergrad

5. Measure and analyze light spectra using filters and spectrometers to identify different light sources, and nanoparticle and light interactions Audience: Both Grad Undergrad

6. Follow and implement written experiment protocols, collect, and analyze data, and write coherent reports presenting experimental findings Audience: Both Grad Undergrad

7. Identify and evaluate an optical imaging setup that was developed in a recently published journal article applying knowledge that was learned in class Audience: Graduate

B M E/ISY E 662 – DESIGN AND HUMAN DISABILITY AND AGING

3 credits.

Design of products for persons with physical, sensory or cognitive impairments is covered as well as the design of standard mass market products. Interdisciplinary teams explore specific disabilities, then design a standard mass market product in competition with each other.

Requisites: Junior standing or member of Engineering Guest Students

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

B M E/CRB 670 – BIOLOGY OF HEART DISEASE AND REGENERATION

3 credits.

Presents diverse topics in contemporary heart biology to facilitate understanding of biological, mechanistic, and experimental concepts of cardiac physiology, disease, and regeneration. Learn cellular and molecular mechanisms underlying heart physiology, function, disease and regenerative ability in various model systems. Includes thinking critically about methodology, experimental design and interpretation, and how conclusions are reached in heart biology through cutting-edge literature.

Requisites: (ZOOLOGY/BIOLOGY/BOTANY 151 and BIOCHEM 501) or graduate/professional standing.

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E 701 – SEMINAR IN BIOMEDICAL ENGINEERING

1 credit.

Presentation of advancements in biomedical engineering research by leaders in the field, accompanied by critical analysis of related literature.

Requisites: Graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Demonstrate understanding of technical presentations of current research in biomedical engineering Audience: Graduate

2. Formulate and articulate a question regarding research presented in a technical seminar Audience: Graduate

3. Analyze current scientific literature to draw connections to research presented in a technical seminar Audience: Graduate

B M E 702 – GRADUATE COOPERATIVE EDUCATION PROGRAM

1-2 credits.

Work experience that combines classroom theory with practical knowledge of operations to provide students with a background on which to develop and enhance a professional career. The work experience is tailored for MS students from within the U.S. as well as eligible international students.

Requisites: Graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: Yes, unlimited number of completions

Last Taught: Spring 2024

Learning Outcomes: 1. Identify and respond appropriately to real-life engineering ethics cases relevant to co-op work Audience: Graduate

2. Synthesize and apply appropriate technical education to real world technical work Audience: Graduate

3. Communicate effectively in writing and speaking with a range of audiences in the workplace, including those without disciplinary expertise Audience: Graduate

4. Develop professional and transferable habits like time management skills, collaborative problem-solving skills, and research skills for learning new information Audience: Graduate

B M E 703 – RESPONSIBLE CONDUCT OF RESEARCH FOR BIOMEDICAL ENGINEERS

2 credits.

Develop an understanding of the elements involved in being a responsible member of the Biomedical Engineering research community. Topics include mentor/mentee relationships, identifying research problems, research integrity, ethics, regulations, and improving the scientific climate.

Requisites: Declared in Biomedical Engineering, Ph.D. or Biomedical Engineering: Research, M.S.

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Interpret research ethics regulations and policies Audience: Graduate

2. Differentiate research misconduct from sloppy behavior Audience: Graduate

3. Identify biased or hostile behaviors Audience: Graduate

4. Develop an individualized plan for graduate training Audience: Graduate

B M E/MED PHYS 710 – ADVANCES IN MEDICAL MAGNETIC RESONANCE

3 credits.

Addresses the theory and applications of magnetic resonance (MR) in medicine, by providing the necessary theoretical background to understand advanced MR techniques including magnetic resonance imaging (MRI).

Requisites: MED PHYS/B M E 568 or 578

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

B M E/M E 715 – ADVANCED TISSUE MECHANICS

3 credits.

Central topics in solid mechanics applied to soft tissues, including analysis of strain in the setting of large deformations, computation of stress in multiple experimental loading configurations, constitutive modeling of biomaterials using hyperelastic strain-energy functions, modeling tissue growth and remodeling, and the main theories for soft tissue failure will be covered. Application of finite elasticity theory in practical laboratory situations, and key papers and concepts in soft tissue mechanics.

Requisites: (M E/B M E 615, E M A 710, or 622 prior to Fall 2024) and graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Fall 2023

Learning Outcomes: 1. Compute strain from multiple different types of marker and image data Audience: Graduate

2. Compute stresses using data from uniaxial, biaxial, and inflation mechanical tests Audience: Graduate

3. Construct and utilize constitutive models appropriate for soft tissues Audience: Graduate

4. Formulate and analyze continuum models of biological growth Audience: Graduate

5. Identify common failure criteria applied to soft tissues Audience: Graduate

B M E 740 – BIOMANUFACTURING ENTREPRENEURSHIP

3 credits.

Industry-relevant concepts of biotechnology innovation and translation, directly connecting lessons and classwork to real-world experience and career opportunities and promoting meaningful and sustained engagement between students and industry representatives. Diverse range of translational biotechnology principles, such as product development in biotechnology, regulating biotechnology products, and quality and compliance in biomanufactured products.

Requisites: Graduate/professional standing

Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement

Repeatable for Credit: No

Last Taught: Spring 2024

Learning Outcomes: 1. Recall, differentiate, and interpret key terms of art and jargon commonly associated with translation, commercial development, and regulation of novel biotechnologies and human therapies Audience: Graduate

2. Describe common tools and strategies used by biotechnology industry to assess project progress, risk, and overall value Audience: Graduate

3. Identify and evaluate business strategy and technology translation approach of a real biotech start-up company applying knowledge that was learned in class Audience: Graduate

4. Produce a product-focused value proposition based on the student's research topic, or of a technology of interest to the student by integrating aspects of a business model canvas and constructing a strategic technology development plan Audience: Graduate

B M E/CHEM/MED PHYS 750 – BIOLOGICAL OPTICAL MICROSCOPY

3 credits.

Covers several aspects of state-of-the-art biological and biophysical imaging with an emphasis on instrumentation, beginning with an overview of geometrical optics and optical and fluorescence microscopy. The bulk of the course will focus on advanced imaging techniques including nonlinear optical processes (multi-photon excitation, second harmonic generation, and stimulated Raman processes) and emerging super-resolution methods. Special emphasis will be given to current imaging literature and experimental design. Knowledge of physics-based optics [such as PHYSICS 202] strongly recommended.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** No**Last Taught:** Fall 2021**Learning Outcomes:** 1. Provide a clear, concise oral presentation critiquing a paper in the literature Audience: Graduate

2. Write a hypothesis driven research proposal and present an oral defense Audience: Graduate

3. Write a critical written assessment of literature papers Audience: Graduate

4. Use course concepts to better design experiments and extract quantitative information Audience: Graduate

5. Articulate a fundamental understanding of the function of a microscope Audience: Graduate

B M E 751 – BIOMEDICAL OPTICS AND BIOPHOTONICS

3 credits.

The study and use of light in the life sciences. Interactions of light with cells and tissue can be used for imaging, measurement, diagnosis, and therapy. Applications include optical imaging, endoscopy, microscopy, resolution enhancement, adaptive optics, Optical Coherence Tomography (OCT), quantitative phase microscopy, spectroscopy (fluorescence, elastic scattering), diffuse optical tomography, and computational modeling of light transport in tissue. Fundamental skills, concepts, and theory used for these applications include geometric optics, lens design, Fourier transforms, polarization, interference, coherence, and scattering theory. Particular emphasis will be placed on current literature and cutting edge instruments and methods.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** No**Last Taught:** Spring 2021**Learning Outcomes:** 1. identify common optical components and describe their fundamental principles Audience: Graduate

2. select an appropriate technique or technology best suited to solve a given research or medical problem and explain the rationale Audience: Graduate

3. solve optical design problems including 1st order optical design of a scanning light microscope Audience: Graduate

4. orally present and critique a recent journal article with a succinct description of the optical methods or concepts employed and evaluate the pros and cons Audience: Graduate

B M E/E C E/MED PHYS 778 – MACHINE LEARNING IN ULTRASOUND IMAGING

3 credits.

Concepts and machine learning techniques for ultrasound beamforming for image formation and reconstruction to image analysis and interpretation will be presented. Key machine learning and deep learning concepts applied to beamforming, compressed sampling, speckle reduction, segmentation, photoacoustics, and elasticity imaging will be evaluated utilizing current peer-reviewed publications.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** No**Last Taught:** Fall 2023

B M E 780 – METHODS IN QUANTITATIVE BIOLOGY

1 credit.

Focuses on understanding the key methods and principles of quantitative biology through a close reading of the primary literature. Topics covered will include deterministic and stochastic methods for modeling cellular systems, techniques in systems and synthetic biology, image processing tools and image analysis for biology, data-driven network models, genomic approaches, single-molecule approaches, and key computational biology tools. This course is intended for graduate students from a variety of backgrounds who are interested in pursuing quantitative biology during their graduate studies.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** No**Last Taught:** Fall 2023

Learning Outcomes: 1. Identify and describe the benefits and limitations of key methods used in the field of quantitative biology Audience: Graduate

2. Critically evaluate experimental and theoretical papers in quantitative biology Audience: Graduate

B M E/CBE 782 – MODELING BIOLOGICAL SYSTEMS

3 credits.

Literature survey of mathematical models in biology at the molecular and cellular levels; application of chemical kinetics and thermodynamics to biological systems; comparison of deterministic and stochastic strategies.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** No**Last Taught:** Spring 2015**B M E/CBE 783 – DESIGN OF BIOLOGICAL MOLECULES**

3 credits.

Introduction to the methodologies for engineering the structure and function of biological molecules, especially proteins. Develop an understanding for the integration of computation and experiment to address biological molecular engineering problems. Knowledge of biochemistry and cell biology [such as BIOCHEM 501 or ZOOLOGY 570] required.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** No**Last Taught:** Spring 2019**B M E 790 – MASTER'S RESEARCH AND THESIS**

1-9 credits.

Under faculty supervision.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** Yes, unlimited number of completions**Last Taught:** Spring 2024**B M E 799 – ADVANCED INDEPENDENT STUDY**

1-5 credits.

Under faculty supervision.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** Yes, unlimited number of completions**Last Taught:** Spring 2024**B M E 890 – PRE-DISSERTATION RESEARCH**

1-9 credits.

Under faculty supervision.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** Yes, unlimited number of completions**Last Taught:** Spring 2024**B M E/B M I/BIOCHEM/CBE/COMP SCI/GENETICS 915 – COMPUTATION AND INFORMATICS IN BIOLOGY AND MEDICINE**

1 credit.

Participants and outside speakers will discuss current research in computation and informatics in biology and medicine. This seminar is required of all CIBM program trainees.

Requisites: Consent of instructor**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** Yes, unlimited number of completions**Last Taught:** Spring 2024**B M E 990 – RESEARCH AND THESIS**

1-9 credits.

Under faculty supervision.

Requisites: Graduate/professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** Yes, unlimited number of completions**Last Taught:** Spring 2024**B M E 999 – ADVANCED INDEPENDENT STUDY**

1-9 credits.

Under faculty supervision.

Requisites: Declared in Biomedical Engineering PhD or professional standing**Course Designation:** Grad 50% - Counts toward 50% graduate coursework requirement**Repeatable for Credit:** Yes, unlimited number of completions**Last Taught:** Fall 2019