

# BIOMEDICAL ENGINEERING, PHD

## REQUIREMENTS

### MINIMUM GRADUATE SCHOOL REQUIREMENTS

Review the Graduate School minimum degree requirements (<https://guide.wisc.edu/graduate/#requirements>) and policies (<https://guide.wisc.edu/graduate/#policies>), in addition to the program requirements listed below.

### MAJOR REQUIREMENTS

#### MODE OF INSTRUCTION

Face to Face	Evening/ Weekend	Online	Hybrid	Accelerated
Yes	No	No	No	No

#### Mode of Instruction Definitions

**Accelerated:** Accelerated programs are offered at a fast pace that condenses the time to completion. Students typically take enough credits aimed at completing the program in a year or two.

**Evening/Weekend:** Courses meet on the UW-Madison campus only in evenings and/or on weekends to accommodate typical business schedules. Students have the advantages of face-to-face courses with the flexibility to keep work and other life commitments.

**Face-to-Face:** Courses typically meet during weekdays on the UW-Madison Campus.

**Hybrid:** These programs combine face-to-face and online learning formats. Contact the program for more specific information.

**Online:** These programs are offered 100% online. Some programs may require an on-campus orientation or residency experience, but the courses will be facilitated in an online format.

### CURRICULAR REQUIREMENTS

#### Requirement Detail

Minimum Credit Requirement	60 credits
Minimum Residence Credit Requirement	32 credits
Minimum Graduate Coursework Requirement	30 credits must be graduate-level coursework. Refer to the Graduate School: Minimum Graduate Coursework (50%) Requirement policy: <a href="https://policy.wisc.edu/library/UW-1244">https://policy.wisc.edu/library/UW-1244</a> ( <a href="https://policy.wisc.edu/library/UW-1244/">https://policy.wisc.edu/library/UW-1244/</a> ).
Overall Graduate GPA Requirement	3.00 GPA required. Refer to the Graduate School: Grade Point Average (GPA) Requirement policy: <a href="https://policy.wisc.edu/library/UW-1203">https://policy.wisc.edu/library/UW-1203</a> ( <a href="https://policy.wisc.edu/library/UW-1203/">https://policy.wisc.edu/library/UW-1203/</a> ).

Other Grade Requirements n/a

Assessments and Examinations PhD candidates are required to pass a comprehensive qualifying examination, preliminary examination, and final oral defense. Deposit of the doctoral dissertation to the Graduate School is required.

Language Requirements No language requirements.

Graduate School Breadth Requirement Breadth is provided via interdisciplinary training. The central aim of biomedical engineers is to unravel gaps in biological knowledge through the use of engineering principles. Thus, the doctoral program is inherently interdisciplinary. Prior to obtaining a PhD warrant, students will prepare a summary of their effort in interdisciplinary coursework and training. The purpose of the summary will be to document the effort to meet the spirit of the minor requirement. The summary must be approved by the student's thesis committee and filed with the department. Students may elect to pursue a doctoral minor or graduate/professional certificate.

### REQUIRED COURSES

Code	Title	Credits
<b>General Requirements</b>		
<i>Research Credits</i>		
Complete 35 credits research:		35
B M E 790	Master's Research and Thesis	
B M E 890	Pre-dissertation Research	
B M E 990	Research and Thesis	
<i>Coursework</i>		
Complete 25 credits of coursework, including the following:		25
B M E 701	Seminar in Biomedical Engineering (taken for 2 semesters)	
B M E 703	Responsible Conduct of Research for Biomedical Engineers	
Complete one set of PhD pathway requirements (credits vary; see below).		
<b>Total Credits</b>		<b>60</b>

Students who follow the PhD coursework guidelines should fulfill the Biomedical Engineering: Research, MS (<https://guide.wisc.edu/graduate/biomedical-engineering/biomedical-engineering-ms/biomedical-engineering-research-ms/>) requirements. They may file for that degree prior to their preliminary examination.

### Biomaterials & Tissue Engineering Pathway <sup>1</sup>

Biomaterials and tissue engineering employ a diverse range of approaches to develop methods to diagnose and treat diseases, create living tissue environments that may be used to restore the function of a damaged organ, and uncover biological mechanisms related to tissue development and disease. Graduate students trained in biomaterials and tissue engineering are expected to gain a detailed understanding of cellular and molecular biology, materials science, and engineering methods relevant to their research focus.

Code	Title	Credits
<b>Biology Requirement</b>		
Complete one of the following:		3

CRB 640	Fundamentals of Stem Cell and Regenerative Biology
CRB 650	Molecular and Cellular Organogenesis
M M & I/PATH-BIO 528	Immunology
ZOOLOGY 570	Cell Biology

**Data Analysis Requirement**

Complete one of the following: 3-4

B M I/STAT 541	Introduction to Biostatistics
B M I/COMP SCI 776	Advanced Bioinformatics
COMP SCI 765	Data Visualization
STAT/F&W ECOL 571	Statistical Methods for Bioscience I
STAT/B M I 877	Statistical Methods for Molecular Biology

**Engineering Requirement**

Relevant options include: 9

B M E/PHM SCI 430	Biological Interactions with Materials
B M E 510	Introduction to Tissue Engineering
B M E 511	Tissue Engineering Laboratory
B M E 520	Stem Cell Bioengineering
B M E 545	Engineering Extracellular Matrices
B M E 550	Introduction to Biological and Medical Microsystems
B M E 602	Special Topics in Biomedical Engineering (CRISPR Genome Editing and Engineering Laboratory)
CBE 540	Polymer Science and Technology
CBE 562	Special Topics in Chemical Engineering (Cellular Biomanufacturing)
CBE 648	Synthetic Organic Materials in Biology and Medicine
CBE 781	Biological Engineering: Molecules, Cells & Systems
M S & E 521	Advanced Polymeric Materials

**Elective credits**

Choose in consultation with your advisor 6

**Total Credits** 21**Biomedical Imaging & Optics Pathway**<sup>1</sup>

Biomedical imaging and optics research develops and utilizes new experimental and computational tools to characterize tissue structure across multiple size scales. A particular focus is on human health, especially with respect to achieving superior diagnostic/prognostic tools for a spectrum of diseased states. Graduate students trained in this pathway are expected to gain a detailed understanding of mathematics, biology and engineering both optical and/or physical methods relevant to their research focus.

Code	Title	Credits
<b>Mathematics Requirement</b> <sup>2</sup>		
MATH 443	Applied Linear Algebra	3

**Biology Requirement**

Complete one of the following: 3-5

ANAT&PHY 335	Physiology
BIOCHEM 501	Introduction to Biochemistry
ZOOLOGY 570	Cell Biology

**Data Analysis Requirement**

Complete one of the following: 3

MED PHYS 674	Data Science in Medical Physics
COMP SCI 319	Data Science Programming I for Research
COMP SCI/E C E/ M E 532	Matrix Methods in Machine Learning
COMP SCI/E C E 766	Computer Vision
COMP SCI/B M I 767	Computational Methods for Medical Image Analysis

**Engineering Requirement**

Relevant options include: 9

B M E/MED PHYS 573	Mathematical Methods in Medical Physics
B M E/MED PHYS 578	Non-Ionizing Diagnostic Imaging
B M E 651	Biophotonics Laboratory
B M E/MED PHYS/PHM COL-M/PHYSICS/RADIOL 619	Microscopy of Life
B M E/MED PHYS 710	Advances in Medical Magnetic Resonance
B M E/CHEM/MED PHYS 750	Biological Optical Microscopy
B M E 751	Biomedical Optics and Biophotonics
B M E 780	Methods in Quantitative Biology
CHEM 668	Biophysical Spectroscopy
MED PHYS/B M E/H ONCOL/PHYSICS 501	Radiation Physics and Dosimetry
MED PHYS/B M E 580	The Physics of Medical Imaging with Ionizing Radiation
MED PHYS 777	Principles of X-ray Computed Tomography

**Elective**

Choose in consultation with your advisor 3

**Total Credits** 21**Biomechanics Pathway**<sup>1</sup>

Biomechanists use experiments and computational tools to investigate the mechanical aspects of biological systems at levels ranging from whole organisms to organs, tissues, and cells. Graduate students trained in biomechanics are expected to gain a detailed understanding of mechanics, mathematics, biology, and engineering relevant to their research focus.

Code	Title	Credits
<b>Mechanics</b>		
To provide depth, 6 credits of Biomechanics courses are required. The remaining 6 credits may be selected from either the Advanced Mechanics or Biomechanics lists.		12
<i>Biomechanics</i>		
B M E/M E 414	Orthopaedic Biomechanics - Design of Orthopaedic Implants	
B M E/M E 415	Biomechanics of Human Movement	
B M E/M E 505	Biofluidics	
B M E/M E 516	Finite Elements for Biological and Other Soft Materials	
B M E 603	Special Topics in Bioinstrumentation and Medical Devices (Image-Based Biomechanics)	
B M E/M E 615	Tissue Mechanics	
B M E/M E 715	Advanced Tissue Mechanics	
<i>Advanced Mechanics</i>		
M E 440	Intermediate Vibrations	
M E/CIV ENGR/ E M A 508	Composite Materials	
M E/E M A 540	Experimental Vibration and Dynamic System Analysis	
M E 563	Intermediate Fluid Dynamics	
M E/E M A 570	Experimental Mechanics	
M E 573	Computational Fluid Dynamics	
E M A 506	Advanced Mechanics of Materials I	
E M A 519	Fracture Mechanics	
E M A/ M S & E 541	Heterogeneous and Multiphase Materials	
E M A 545	Mechanical Vibrations	
E M A 605	Introduction to Finite Elements	
E M A/E P 615	Micro- and Nanoscale Mechanics	
E M A 630	Viscoelastic Solids	
E M A 700	Theory of Elasticity	
E M A 710	Mechanics of Continua	
<b>Biosciences</b>		
Complete one of the following:		3-5
ANAT&PHY 335	Physiology	
ANAT&PHY 435	Fundamentals of Human Physiology	
BIOCHEM/ GENETICS/ MD GENET 620	Eukaryotic Molecular Biology	
CRB/B M E 670	Biology of Heart Disease and Regeneration	
KINES 773	Cardiorespiratory Adaptions to Environment and Exercise	
ZOOLOGY 570	Cell Biology	
<b>Electives</b>		
Choose in consultation with your advisor		6
<b>Total Credits</b>		<b>21</b>

**Medical & Microdevices Pathway<sup>1</sup>**

Medical and microdevices involve the use of electronic and computational tools to develop devices used in diagnosis and treatment of disease ranging from the systemic to the cellular and molecular levels.

Code	Title	Credits
<b>Mathematics Requirement<sup>2</sup></b>		
Complete one of the following:		3
MATH 443	Applied Linear Algebra	
MATH 519	Ordinary Differential Equations	
MATH 619	Analysis of Partial Differential Equations	
<b>Biology Requirement</b>		
Complete one of the following:		3-5
ANAT&PHY 335	Physiology	
BIOCHEM 501	Introduction to Biochemistry	
BIOCHEM/ GENETICS/ MICROBIO 612	Prokaryotic Molecular Biology	
BIOCHEM/ GENETICS/ MD GENET 620	Eukaryotic Molecular Biology	
PATH 750	Cellular and Molecular Biology/ Pathology	
PATH 752	Cellular and Molecular Biology/ Pathology Seminar	
ZOOLOGY/ PSYCH 523	Neurobiology	
ZOOLOGY 570	Cell Biology	
<b>Data Analysis Requirement</b>		
Complete one of the following:		3-4
B M I/STAT 541	Introduction to Biostatistics	
B M I/STAT 542	Introduction to Clinical Trials I	
B M I/ COMP SCI 576	Introduction to Bioinformatics	
B M I/ COMP SCI 776	Advanced Bioinformatics	
<b>Engineering Requirement</b>		
Relevant options include:		9
B M E/E C E 462	Medical Instrumentation	
B M E/ MED PHYS 535	Introduction to Energy-Tissue Interactions	
B M E 550	Introduction to Biological and Medical Microsystems	
B M E 602	Special Topics in Biomedical Engineering (Introduction to Neuroengineering)	
B M E 640	Medical Devices Ecosystem: The Path to Product	
B M E 651	Biophotonics Laboratory	
B M E/CHEM/ MED PHYS 750	Biological Optical Microscopy	
<b>Elective</b>		
Choose in consultation with your advisor		3
<b>Total Credits</b>		<b>21</b>

## Neuroengineering Pathway<sup>1</sup>

Neuroengineering is the convergence of neuroscience, computation, device development, and mathematics to improve human health. Neuroengineering brings together state-of-the-art technologies for the development of devices and algorithms to assist those with neural disorders. It is also used to reverse engineer living neural systems via new algorithms, technologies and robotics. Students pursuing this pathway are involved in all of these endeavors so as the next generation of engineers, they will transcend the traditional boundaries of neuroscience, technology, engineering and mathematics.

Code	Title	Credits
<b>Data Analysis Requirement</b>		
Complete one of the following:		3
COMP SCI 319	Data Science Programming I for Research	
COMP SCI/E C E/ M E 532	Matrix Methods in Machine Learning	
COMP SCI/ E C E 533	Image Processing	
COMP SCI/ B M I 567	Biomedical Image Analysis	
<b>Engineering Requirement</b>		
Relevant options include:		9
B M E 520	Stem Cell Bioengineering	
B M E 550	Introduction to Biological and Medical Microsystems	
B M E 602	Special Topics in Biomedical Engineering (Introduction to Neuroengineering)	
B M E 640	Medical Devices Ecosystem: The Path to Product	
E C E/B M E 462	Medical Instrumentation	
E C E/B M E 463	Computers in Medicine	
<b>Biology Requirement</b>		
Complete one of the following:		3
KINES 721	Neural Basis for Movement	
KINES 861	Principles of Motor Control and Learning	
NEUROL 735	Neurobiology of Disease	
NTP/ NEURODPT 610	Cellular and Molecular Neuroscience	
NTP/NEURODPT/ PSYCH 611	Systems Neuroscience	
PSYCH 610	Design and Analysis of Psychological Experiments I	
PSYCH 733	Perceptual and Cognitive Sciences	
<b>Electives</b>		
Choose in consultation with your advisor		6
<b>Total Credits</b>		<b>21</b>

## Systems & Synthetic Biology Pathway<sup>1</sup>

Systems and synthetic biology utilizes experimental and computational tools in an iterative fashion to analyze and regulate biological systems.

Students interested in earning a doctoral minor in Quantitative Biology (<https://guide.wisc.edu/graduate/biomedical->

**engineering/quantitative-biology-doctoral-minor/**): enrollment in B M E 780 Methods in Quantitative Biology is a requirement. Additionally, students will need to take one additional 3-credit course in quantitative science, biology, or integrated biology/quantitative science from the approved list of courses in the doctoral minor (this course counts toward the elective credits for this pathway).

Code	Title	Credits
<b>Mathematics Requirement</b>		
Complete one of the following: <sup>2</sup>		3
MATH 443	Applied Linear Algebra	
MATH 519	Ordinary Differential Equations	
MATH 619	Analysis of Partial Differential Equations	
<b>Biology Requirement</b>		
Complete one of the following:		3
BIOCHEM 501	Introduction to Biochemistry	
BIOCHEM/ GENETICS/ MICROBIO 612	Prokaryotic Molecular Biology	
BIOCHEM/ GENETICS/ MD GENET 620	Eukaryotic Molecular Biology	
M M & I/PATH- BIO 528	Immunology	
ZOOLOGY 570	Cell Biology	
<b>Data Analysis Requirement</b>		
Complete one of the following:		3
B M I/STAT 541	Introduction to Biostatistics	
B M I/ COMP SCI 576	Introduction to Bioinformatics	
COMP SCI 319	Data Science Programming I for Research	
COMP SCI/E C E/ M E 532	Matrix Methods in Machine Learning	
<b>Engineering Requirement</b>		
Relevant options include:		9
B M E 550	Introduction to Biological and Medical Microsystems	
B M E 556	Systems Biology: Mammalian Signaling Networks	
B M E 602	Special Topics in Biomedical Engineering (CRISPR Genome Editing and Engineering Laboratory)	
B M E 780	Methods in Quantitative Biology	
CBE/B M E 560	Biochemical Engineering	
CBE 660	Intermediate Problems in Chemical Engineering	
CBE 781	Biological Engineering: Molecules, Cells & Systems	
<b>Elective</b>		
Choose in consultation with your advisor		3
<b>Total Credits</b>		<b>21</b>

### **Guidelines for students who earned a master's degree in another field at UW-Madison**

1. Students who have earned a master's degree in another field at UW-Madison should contact the Associate Chair of the PhD Degree to understand remaining course requirements. A maximum of 7 credits can be counted from a separate MS degree, in compliance with the Graduate School: Double Degrees (<https://policy.wisc.edu/library/UW-1205/>) policy.
2. Master's degree students who have been absent for five or more years lose all degree credits earned before their absence.
3. All students with a prior master's degree will need to complete the Qualifying Exams and Preliminary Exam requirements even if coursework requirements have been met. Please discuss your specific plan with the Associate Chair of the PhD Degree.

### **Footnotes**

- <sup>1</sup> These pathways are internal to the program and represent different curricular paths a student can follow to earn this degree. Pathway names do not appear in the Graduate School admissions application, and they will not appear on the transcript.
- <sup>2</sup> The math requirement can be satisfied with a B- or better in the equivalent course in undergraduate. For approval, please e-mail the Associate Chair of the PhD Degree a copy of your unofficial transcript and indicate the course you are proposing to use. The credits do not transfer; you will instead be able to take an additional 3 credits of electives.