**Biomedical Engineering, Ph.D.**

**Requirements**

**Minimum Graduate School Requirements**

Review the Graduate School minimum academic progress and degree requirements (http://guide.wisc.edu/graduate/#policiesandrequirements#text), in addition to the program requirements listed below.

**Major Requirements**

**Mode of Instruction**

<table>
<thead>
<tr>
<th>Face to Face</th>
<th>Evening/Weekend</th>
<th>Online</th>
<th>Hybrid</th>
<th>Accelerated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**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**

**Required Courses**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Credits (B M E 790, 890, 990)</td>
<td>at least 30</td>
<td></td>
</tr>
<tr>
<td>Coursework, including:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 semesters of B M E 701</td>
<td>at least 25</td>
<td></td>
</tr>
<tr>
<td>B M E 703</td>
<td>Responsible Conduct of Research for Biomedical Engineers</td>
<td>2</td>
</tr>
<tr>
<td>One set of Ph.D. pathway requirements (credits vary; see below)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td><strong>Total Credits</strong></td>
<td></td>
<td>60</td>
</tr>
</tbody>
</table>

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

**Biomaterials & Tissue Engineering Pathway**

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.

**Other Grade Requirements**

- **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 Ph.D. 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**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRB 640</td>
<td>Fundamentals of Stem Cell and Regenerative Biology</td>
<td>3</td>
</tr>
<tr>
<td>CRB 650</td>
<td>Molecular and Cellular Organogenesis</td>
<td></td>
</tr>
<tr>
<td>M M &amp; I/PAT-BIO 528</td>
<td>Immunology</td>
<td></td>
</tr>
<tr>
<td>ZOOLOGY 570</td>
<td>Cell Biology</td>
<td></td>
</tr>
<tr>
<td><strong>Data Analysis Requirement</strong></td>
<td></td>
<td>3-4</td>
</tr>
</tbody>
</table>
Biomedical Imaging & Optics Pathway
Biomedical imaging and optics research develops and utilizes 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.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
</table>
| Mathematics Requirement | **3**  
MATH 443  Applied Linear Algebra | **3**    |
| Biology Requirement | **3-5**  
ANAT&PHY 335  Physiology  
BIOCHEM 501  Introduction to Biochemistry  
ZOOLOGY 570  Cell Biology | **3-5**  |
| Data Analysis Requirement | **3**  
COMP SCI/ECE 532  Matrix Methods in Machine Learning  
COMP SCI/ECE 766  Computer Vision | **3**    |

Biomechanics Pathway
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.

<table>
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<tr>
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</table>
| Mechanics | **12**  
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.  
**Biomechanics**  
B ME/M E 414  Orthopaedic Biomechanics - Design of Orthopaedic Implants  
B ME/M E 415  Biomechanics of Human Movement  
B ME/M E 505  Biofluidics  
B ME/M E 516  Finite Elements for Biological and Other Soft Materials  
B ME 603  Special Topics in Bioinstrumentation and Medical Devices (Image-Based Biomechanics) | **12**    |
### Biomedical Engineering, Ph.D.

**Advanced Mechanics**
- M E 440 Intermediate Vibrations
- M E/CIV ENGR/EMA 508 Composite Materials
- M 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 622 Mechanics of Continua
- E M A 630 Viscoelastic Solids
- E M A 700 Theory of Elasticity

**Biosciences**
- 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

**Elective credits chosen in consultation with your advisor**

**Total Credits**

### Medical & Microdevices Pathway
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.

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<tr>
<td>MATH 443</td>
<td>Applied Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>MATH 519</td>
<td>Ordinary Differential Equations</td>
<td></td>
</tr>
<tr>
<td>MATH 619</td>
<td>Analysis of Partial Differential Equations</td>
<td></td>
</tr>
</tbody>
</table>

### Engineering Requirement
- B M E/E C E 462 Medical Instrumentation
- B M E 515 Therapeutic Medical Devices
- 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

**Elective credits chosen in consultation with your advisor**

**Total Credits**

### Neuroengineering Pathway
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.

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<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>COMP SCI 319</td>
<td>Data Science Programming I for Research</td>
<td>3</td>
</tr>
<tr>
<td>COMP SCI/E C E/ M E 532</td>
<td>Matrix Methods in Machine Learning</td>
<td></td>
</tr>
<tr>
<td>COMP SCI/ E C E 533</td>
<td>Image Processing</td>
<td></td>
</tr>
<tr>
<td>COMP SCI/ B M I 567</td>
<td>Medical Image Analysis</td>
<td></td>
</tr>
</tbody>
</table>

**Engineering Requirement**
- B M E 515 Therapeutic Medical Devices
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’s Double Degrees policy (https://grad.wisc.edu/documents/double-degrees/).

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

1. 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.

2. The math requirement can be waived by a B- or better in the equivalent course in undergraduate. To request this waiver, 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.