

BIOMEDICAL ENGINEERING PHD

Degree Requirements

The following requirements are in addition to, or further elaborate upon, those requirements outlined in The Graduate School Policy Guide (<https://catalogs.northwestern.edu/tgs/academic-policies-procedures/>).

PhD

Total Units Required:

- Students entering with a BS degree: 12
- Students entering with an MS degree: 9
- Students enrolled in the DPT/PhD program: 9
- Students enrolled in the MSTP program: 6

Students in the PhD program enter into one of 6 “tracks” representing the broad research areas in our department. The purpose of these tracks is to guide students in their course selection, providing depth in areas relevant to their selected research area. The current tracks offered are:

- Biomaterials
- Imaging and Biophotonics
- Mechanics and Transport
- Neural Engineering
- Rehabilitation
- Regenerative Medicine and Engineering

Course Requirements

Students entering with a BS degree must complete a minimum of 12 courses at Northwestern University. These are to include the required courses listed below, as well as sufficient additional coursework to meet the described competencies for the selected course track. All additional courses must be in Engineering, Science or Math. Students are to work with their primary BME adviser to ensure that the plan of study is sufficient for meeting all specified competencies. All courses used to meet these minimum requirements must be for a letter grade (i.e. P/N courses are not accepted) and none can be a 499 (research credit).

The requirements for **students entering with an MS degree or students in the MSTP or PhD/DPT programs** are identical to those for students entering with a BS, with the following exceptions. Note that these students must also demonstrate competency in all areas of the selected course track.

- Students entering with an MS or in the PhD/DPT programs:
 - A minimum of nine 300 or 400-level graduate courses must be taken for a letter grade (i.e. P/N courses are not accepted). One of these may be a 499 (research credit). All of these courses must be science, engineering or mathematics courses.
- Students in the MSTP:
 - A total of at least six 300 or 400-level graduate courses for a letter grade (i.e. P/N courses are not accepted). None of these may be a 499 (research credit). All of these courses must be science, engineering or mathematics courses.

The following courses are required for all students in the PhD program:

- BMD_ENG 495-0 Special Advanced Topics in Biomedical Engineering (Experimental Design and Measurement for Biomedical Engineering Graduate Students)
- All first-year students are required to complete BMD_ENG 512-0 Graduate Research Seminar in Biomedical Engineering in the fall, winter, and spring quarters. Upon petition to the Graduate Program Chair, a student may delay completion of BMD_ENG 512-0 until a subsequent time if the student is enrolled in a class that meets in conflict with BMD_ENG 512-0. This requirement does not earn course credit.
- All first-year students are required to complete GEN_ENG 519-0 Responsible Conduct for Research Training. This requirement does not earn course credit.

Additional course requirements are specified for each track below:

Course	Title
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Biomaterials Course Track

Students are required to complete the courses below as a part of the course component of the qualifying exam:

BMD_ENG 343-0	Biomaterials and Medical Devices
MECH_ENG 422-0	Statistical Mechanics for Applications

Course	Title
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Imaging and Biophotonics Course Track

Students are required to take two (2) of the following courses, specific to their concentration, as a part of the course component of the qualifying exam:

MRI Concentration

BMD_ENG 327-0	Magnetic Resonance Imaging
BMD_ENG 427-0	Advanced MR Imaging
BMD_ENG 495-0	Special Advanced Topics in Biomedical Engineering (Modeling of Medical Images)

Biophotonics Concentration

BMD_ENG 333-0	Modern Optical Microscopy & Imaging
BMD_ENG 429-0	Advanced Physical and Applied Optics
PHYSICS 357-0	Optics Laboratory

Students are also required to take at least one (1) of the following courses:

ELEC_ENG 302-0	Probabilistic Systems
ELEC_ENG 332-0	Introduction to Computer Vision
ELEC_ENG 420-0	Digital Image Processing

Course	Title
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Mechanics and Transport Course Track

Students are required to complete the courses below as a part of the course component of the qualifying exam:

BMD_ENG 371-0	Mechanics of Biological Tissue
BMD_ENG 478-0	Transport Fundamentals

Course	Title
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Neural Engineering Course Track

Students are required to take two (2) of the following courses as a part of the course component of the qualifying exam:

BMD_ENG 468-0	Computational Neuromechanics and Neuroethology
BMD_ENG 462-0	Neural Engineering: Sensory Acquisition through Movement
BMD_ENG 463-0	Neuropathophysiology
BMD_ENG 469-0	Neural Control and Mechanics of Movement

Students are also required to take at least one (1) of the following courses:

ES_APPM 370-1	Introduction to Computational Neuroscience
COMP_SCI 349-0	Machine Learning

ELEC_ENG 435-0	Deep Learning: Foundations, Applications, and Algorithms
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400 level Electrical Engineering or Computer Science course relevant to Machine Learning

Course	Title
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Regenerative Medicine and Engineering Course Track

Students are required to take two (2) of the following courses as a part of the course component of the qualifying exam:

BMD_ENG 346-0	Tissue Engineering
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BMD_ENG 444-0	Organic Nanomaterials
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BMD_ENG 347-0	Foundations of Regenerative Engineering
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or BMD_ENG 348-0	Applications of Regenerative Engineering
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Students are also required to take at least one (1) of the following courses:

BMD_ENG 343-0	Biomaterials and Medical Devices
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BMD_ENG 344-0	Biological Performance of Materials
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MECH_ENG 422-0	Statistical Mechanics for Applications
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Course	Title
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Rehabilitation Course Track

Students are required to take one (1) of the following courses as a part of the course component of the qualifying exam:

BMD_ENG 463-0	Neuropathophysiology
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BMD_ENG 469-0	Neural Control and Mechanics of Movement
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Students are required to take one (1) of the following courses as a part of the course component of the qualifying exam:

MECH_ENG 314-0	Machine Dynamics
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ELEC_ENG 390-0	Introduction to Robotics
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Students are also required to take at least one (1) of the following courses:

BMD_ENG 366-0	Biomechanics of Movement
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IEMS 315-0	Stochastic Models
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COMP_SCI 349-0	Machine Learning
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ELEC_ENG 435-0	Deep Learning: Foundations, Applications, and Algorithms
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- Final Evaluations: oral defense of dissertation when all other requirements completed
- Teaching Experience: The teaching requirement is to be fulfilled by serving for at least one quarter as a full-time TA (approximate time commitment: 20 hr/week) for a BME course.
- Publication Requirement: All students are required to be the primary author on a peer-reviewed journal article accepted for publication prior to defending their PhD research.

Other PhD Degree Requirements

- Examinations: PhD Qualifying exams must be completed by the end of the second year of study. Prior to taking the oral examination, students must complete at least 8 courses (MSTP students must take all 6 courses), including the required physiology and mathematics courses, and the two required courses for the selected research track. In addition to the oral examination, administered by the department in June each year, students must pass the course component and the research component of the qualifying process. Students must earn at least an A- in the two required courses for the selected course track to pass the course component, or else an additional written exam is required. To complete the research component, students must present their initial research project to their PhD research committee by March 31 of their 2nd year, who evaluate their research progress on a pass/fail basis.
- MS degree: Students entering with a BS degree who are not enrolled in the MSTP or DPT/PhD program must complete an MS degree. Within the PhD program, completion of the three components of the PhD qualifying exam and completion of an additional writing requirement satisfies the MS degree requirements. The writing requirement can be satisfied by submitting an original manuscript to a peer-reviewed journal or submitting a thesis to the BME department.
- PhD Dissertation: original, independent research