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 science, engineering, or mathematics. Students are to work with their primary BME advisor 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.

General Course Requirements

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

Course	Title
BMD_ENG 512-0	Graduate Research Seminar in Biomedical Engineering (0 credits - 3 quarters)
BMD_ENG 407-0	Experimental Design and Measurement (1 credit) [1]
GEN_ENG 519-0	Responsible Conduct for Research Training (0 credits)
Competency: Physiological and Biological Sciences	
BMD_ENG 304-0	Quantitative Systems Physiology
BMD_ENG 305-0	Quantitative Systems Physiology
BMD_ENG 306-0	Quantitative Systems Physiology
BMD_ENG 404-1	Special Topics in Systems Physiology
BMD_ENG 404-2	Special Topics in Systems Physiology
BMD_ENG 404-3	Special Topics in Systems Physiology
Competency: Quantitative Sciences and Engineering	
STAT 330-1	Applied Statistics for Research 1 (1 credit)
or IEMS 303-0	Statistics
ES_APPM 395-0	Special Topics (1 credit - Methods of Applied Mathematics)

[1] Be sure to complete stats requirements (below) before enrolling in BMD_ENG 407-0 Experimental Design and Measurement , either by taking STAT 330-1 Applied Statistics for Research 1 or IEMS 303-0 Statistics or by petitioning out.

[2] Taken only if deemed necessary by adviser and/or Director of Graduate Studies

Track-specific Course Requirements

Biomaterials Track

Course	Title
Biomaterials Course Track	
Students are required to complete the courses below as a part of the course component of the qualifying exam:	
BMD_ENG 344-0	Biological Performance of Materials (1 credit)
BMD_ENG 343-0	Biomaterials and Medical Devices (1 credit)
MECH_ENG 422-0	Statistical Mechanics for Applications (1 credit)

Imaging and Biophotonics Track

Course	Title
Imaging and Biophotonics Course Track	
Students are required to complete the courses below as a part of the course component of the qualifying exam:	
ELEC_ENG 359-0	Digital Signal Processing (1 credit)
PHYSICS 333-1	Advanced Electricity & Magnetism (1 credit)
Students are required to take two 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 (1 credit)
BMD_ENG 427-0	Advanced MR Imaging (1 credit)
BMD_ENG 495-0	Special Advanced Topics in Biomedical Engineering (1 credit - MRI Modeling of Brain Physiology)
Biophotonics Concentration	
BMD_ENG 333-0	Modern Optical Microscopy & Imaging (1 credit)
BMD_ENG 429-0	Advanced Physical and Applied Optics (1 credit)
PHYSICS 357-0	Optics Laboratory

Mechanics and Transport Track

Course	Title
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 452-0	Transport Through Connective Tissue (1 credit)
BMD_ENG 478-0	Transport Fundamentals (1 credit) [1]

[1] Students without prior transport coursework should enroll in BMD_ENG 377-0 Intermediate Fluid Mechanics before taking BMD_ENG 378-0 Transport Fundamentals.

Neural Engineering Track

Course	Title
Neural Engineering Course Track	
Students are required to take two of the following courses as a part of the course component of the qualifying exam:	
BMD_ENG 462-0	Sensory Acquisition (1 credit)
BMD_ENG 468-0	Decision-Making in the Wild: Measurement and Models (1 credit)
BMD_ENG 463-0	Advanced Signal Processing Methods in Neuropathophysiology (1 credit)
BMD_ENG 469-0	Neural Control and Mechanics of Movement (1 credit)
Additional competency courses for neural engineering	
NUIN 440-0	Advanced Neuroanatomy (1 credit)
ELEC_ENG 359-0	Digital Signal Processing (1 credit)
MECH_ENG 390-0	Intro to Dynamic Systems (1 credit)
Students are also required to take at least one of the following courses:	
ES_APPM 370-1	Introduction to Computational Neuroscience (1 credit)
COMP_SCI 349-0	Machine Learning (1 credit)
ELEC_ENG 435-0	Deep Learning: Foundations, Applications, and Algorithms (1 credit)
With approval from DGS, any 400 level ELEC_ENG or COMP_SCI course related to machine learning (1 credit)	

Regenerative Medicine and Engineering Track

Course	Title
Regenerative Medicine and Engineering Course Track	
Required courses	
BMD_ENG 343-0	Biomaterials and Medical Devices (1 credit)
BMD_ENG 344-0	Biological Performance of Materials (1 credit)
MECH_ENG 422-0	Statistical Mechanics for Applications (1 credit)
Additional competency courses	
BIOL_SCI 315-0	Advanced Cell Biology (1 credit)
Students are required to take two of the following courses as a part of the course component of the qualifying exam:	
BMD_ENG 346-0	Tissue Engineering (1 credit)
BMD_ENG 444-0	Organic Nanomaterials (1 credit)
BMD_ENG 347-0	Foundations of Regenerative Engineering (1 credit)
BMD_ENG 348-0	Applications of Regenerative Engineering (1 credit)

Rehabilitation Track

Course	Title
Rehabilitation Course Track	
Students are required to take at least one of the following courses as a part of the course component of the qualifying exam:	
BMD_ENG 366-0	Biomechanics of Movement (1 credit)
IEMS 315-0	Stochastic Models (1 credit)

Course	Title
ELEC_ENG 435-0	Deep Learning: Foundations, Applications, and Algorithms (1 credit)
COMP_SCI 349-0	Machine Learning (1 credit)
Additional competency courses	
NUIN 440-0	Advanced Neuroanatomy (1 credit)
MECH_ENG 390-0	Intro to Dynamic Systems (1 credit)
Students are required to take one of the following courses in each section below as a part of the course component of the qualifying exam:	
Take one of the following	
BMD_ENG 463-0	Advanced Signal Processing Methods in Neuropathophysiology (1 credit)
BMD_ENG 469-0	Neural Control and Mechanics of Movement (1 credit)
Take one of the following	
MECH_ENG 314-0	Machine Dynamics (1 credit)
ELEC_ENG 390-0	Introduction to Robotics (1 credit)

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 9 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, who evaluate their research progress on a pass/fail basis, by March 31 of their second year.
- 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
- 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.