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

**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**
--- | ---
**Materials Course Track**
Students are required to complete the courses below as a part of the course component of the qualifying exam:
- BMD_ENG 434-0 Biologics and Medical Devices
- MECH_ENG 422-0 Statistical Mechanics for Applications

**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

**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 471-0 Mechanics of Biological Tissue
- BMD_ENG 478-0 Transport Fundamentals

**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 461-0 Neural Engineering: 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
### Course Title

**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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMD_ENG 346-0</td>
<td>Tissue Engineering</td>
</tr>
<tr>
<td>BMD_ENG 444-0</td>
<td>Organic Nanomaterials</td>
</tr>
<tr>
<td>BMD_ENG 349-1</td>
<td>or BMD_ENG 349-2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMD_ENG 343-0</td>
<td>Biomaterials and Medical Devices</td>
</tr>
<tr>
<td>BMD_ENG 344-0</td>
<td>Biological Performance of Materials</td>
</tr>
<tr>
<td>MECH_ENG 422-0</td>
<td>Statistical Mechanics for Applications</td>
</tr>
</tbody>
</table>

**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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMD_ENG 463-0</td>
<td>Neuropathophysiology</td>
</tr>
<tr>
<td>BMD_ENG 469-0</td>
<td>Neural Control and Mechanics of Movement</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MECH_ENG 314-0</td>
<td>Machine Dynamics</td>
</tr>
<tr>
<td>ELEC_ENG 390-0</td>
<td>Introduction to Robotics</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMD_ENG 366-0</td>
<td>Biomechanics of Movement</td>
</tr>
<tr>
<td>IEMS 315-0</td>
<td>Stochastic Models</td>
</tr>
<tr>
<td>COMP_SCI 349-0</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>ELEC_ENG 435-0</td>
<td>Deep Learning: FAA</td>
</tr>
</tbody>
</table>

### 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 article accepted for publication prior to defending their PhD research.

- **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.