

**Course Requirements: ALL STUDENTS QUALS 2022 AND LATER**

**Petitioning out of a course does not reduce the total number of credits you must take.**

- Students entering with a BS degree must complete a minimum of 12 courses. None of them can be BME 499
- Students entering with an MS degree must complete a minimum of 9 courses. One of them can be BME 499
- Students in the DPT program must complete a minimum of 9 courses. One of them can be BME 499
- Students in the MSTP program must complete a minimum of 6 courses. None of them can be BME 499

Prerequisite courses			
We generally assume you have taken these courses as an undergrad, but some students with more background in physiology and biology than in engineering may not have taken them. If you have not taken them, you should take them in your first year. They do not count for credit towards your grad degree.			
Number	Title	Credits	What do I do if I need to take these courses?
Math 234	Multiple Integration and Vector Calculus	0	Contact DGS (DGS_BME@northwestern.edu)
Math 240	Linear Algebra	0	

Required Courses (typically taken in your first year, or petition out)		Credits	Can I petition out?	
<b>General</b>				
BMD_ENG 512	Graduate Research Seminar (3 quarters)	0	No	
GEN_ENG 519	Responsible Conduct of Research (RCR)	0	No	
BMD_ENG 407*	Experimental Design and Measurement	1	No	
*Be sure to complete stats requirements (below) <i>before</i> enrolling in BMD_ENG 407, either by taking Stat 330 or IEMS 303, or by petitioning out.				
<b>Competency: Physiological and Biological Sciences</b>				
BMD_ENG 401	Neurophysiology	1	Yes	We anticipate that most students who have completed a BME undergrad degree will have completed similar courses, so petitioning out is an option. These courses represent fundamental competencies that all students must know for their qualifying exams.
BMD_ENG 402	Cardiopulmonary	1	Yes	
BMD_ENG 403	Renal, Digestive, Endocrine, Metabolic Physiology	1	Yes	
<b>Competency: Quantitative Sciences and Engineering</b>				
Stat 330 or IEMS 303	Introductory Statistics	1	Yes	
ES_APPM 395	Methods of Applied Mathematics	1	Yes	

General notes when forming a Plan of Study:

- Courses with either a 395 or 495 number indicate the course is new. *There may be multiple courses with these numbers in every department, so you should pay particular attention to the name of the course and the instructor.* These courses are typically assigned a permanent, unique number within a 1 – 2 years.
- To count towards your degree, all courses:
  - Must be eligible for credit in the Graduate School (TGS).
  - Must be in Engineering, Science, or Math. Courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.
- Students are required to review all courses with their advisor.
- You must submit your plan of study to GSTS by the start of winter quarter to obtain the approval of DGS.

## Biomaterials Track Requirements and Recommendations

Remember that courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.

Required Courses: Biomaterials Track			
Additional Competency Courses for Biomaterials		Credits	Can I petition out?
BMD_ENG 344	Biological Performance of Materials	1	Yes, but petitioning out requires advisor approval before DGS approval (two approvals needed).
<b>Courses required for the coursework component of PhD Candidacy. Take both of the following.</b> You must receive a grade of A- or better in both courses. Otherwise, you must pass a written qualifying exam for the course(s) in which a grade lower than an A- was received.			
BMD_ENG 343	Biomaterials and Medical Devices	1	No
MECH_ENG 422	Statistical Mechanics for Applications	1	No

### Additional Courses Relevant to Biomaterials

These are suggestions that are not required but may be of interest.

BMD\_ENG 314 (Models of Biochemistry and Molecular Biology) BMD\_ENG 444 (Organic Nanomaterials)

BMD\_ENG 346 (Tissue Engineering)

BMD\_ENG 353 (Bioelectronics)

BIOL\_SCI 390 (Advanced Molecular Biology)

CHEM 411 (Organic Spectroscopy)

CHEM\_ENG 475 (Cell-Material Interactions)

MAT\_SCI 380 (Intro to Surface Science & Spectroscopy)

MAT\_SCI 460 (Electron Microscopy)

## Imaging and Biophotonics Track Requirements and Recommendations

Remember that courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.

<b>Required Courses: Imaging and Biophotonics Track.</b>						
<b>Additional Competency Courses for Imaging and Biophotonics</b>				<b>Credits</b>	<b>Can I petition out?</b>	
	ELEC_ENG 359	Digital Signal Processing		1	Yes, but petitioning out requires advisor approval before DGS approval (two approvals needed).	
	Physics 333-1	Advanced Electricity and Magnetism		1		
<b>Courses required for the coursework component of PhD Candidacy. Take two courses in one of the concentrations below. You must receive a grade of A- or better in both courses. Otherwise, you must pass a written qualifying exam for the course(s) in which a grade lower than an A- was received.</b>						
<b>MRI Concentration: take two of the following</b>				<b>Credits</b>	<b>Can I petition out?</b>	
	BMD_ENG 327	Magnetic Resonance Imaging		1	No	
	BMD_ENG 427	Advanced MRI Imaging		1	No	
	BMD_ENG 495	MRI Modeling of Brain Physiology		1	No	
<b>Biophotonics Concentration: take two of the following</b>				<b>Credits</b>	<b>Can I petition out?</b>	
	BMD_ENG 333	Optical Microscopy		1	No	
	BMD_ENG 429	Advanced Physical and Applied Optics		1	No	
	Physics 357	Optics Laboratory		1	No	

### Additional Courses Relevant to Imaging and Biophotonics

These are suggestions that are not required but may be of interest

BMD\_ENG 333 (Modern Optical Microscopy & Imaging)  
 BMD\_ENG 343 (Biomaterials and Medical Devices)  
 BMD\_ENG 344 (Biological Performance of Materials)  
 BMD\_ENG 377 (Intermediate Fluid Mechanics)  
 BMD\_ENG 444 (Organic Nanomaterials)  
 BMD\_ENG 463 (Systems Neuropathophysiology)  
 BMD\_ENG 475 (Cardiovascular Protective Engineering)  
 BMD\_ENG 478-0-20 (Advanced Mass and Heat Transfer)\*\*\*  
 BMD\_ENG 452 (Transport Through Connective Tissues)

ELEC\_ENG 302 (Probabilistic Systems)  
 ELEC\_ENG 308 (Applied Electromagnetics and Photonics)  
 ELEC\_ENG 332 (Intro to Computer Vision)  
 ELEC\_ENG 359 (Digital Signal Processing)  
 ELEC\_ENG 379 (Lasers and Coherent Optics)  
 ELEC\_ENG 386 (Computational Electromagnetics and Photonics)  
 ELEC\_ENG 395 (Cardiovascular Instrumentation)  
 ELEC\_ENG 418 (Advanced Digital Signal Processing)  
 ELEC\_ENG 420 (Digital Image Processing)  
 Physics 333-2 (Physics of Electrodynamics)

\*\*\* If you have not taken a course in fluid mechanics as an undergraduate, then you should take BMD\_ENG 377 before BMD\_ENG 478.

## Mechanics and Transport Track requirements and recommendations

Remember that courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.

Required Courses: Mechanics and Transport Track				
Courses required for the coursework component of PhD Candidacy. Take two of the following. You must receive a grade of A- or better in both courses. Otherwise, you must pass a written qualifying exam for the course(s) in which a grade lower than an A- was received.				
Number	Title	Credits	Can I petition out?	
BME 452	Transport through Connective Tissue	1	No	
BMD_ENG 478*	Advanced Mass and Heat Transfer	1	No	
*Students without prior transport coursework should enroll in BMD_ENG 377 before taking BMD_ENG 478.				
<b>NOTE:</b> Faculty in Mechanics and Transport RECOMMEND you take BMD_ENG 452 (Transport through Connective Tissues), but it is not required.				

## Additional Courses Relevant to Mechanics and Transport

These are suggestions that are not required but may be of interest.

### BMD\_ENG 452 (Transport through Connective Tissues) - recommended

CHEM\_ENG 424-1,2 (Transport Phenomena)

CHEM\_ENG 462 (Viscoelasticity and Flow in Polymer Systems)

CIV\_ENV 356 (Transport Processes in Porous Media)

ES\_APPM 426 (Theory of Flows with Small Inertia)

ES\_APPM 420-1 (Asymptomatic and Perturbation Methods in Applied Mathematics)

MECH\_ENG 362 (Stress Analysis)

MECH\_ENG 327 (Finite Elements Methods in Mechanics)

PHYSICS 416 (Introduction to Statistical Mechanics)

PHYSICS 420 (Statistical Physics)

## Regenerative Medicine and Engineering Track Requirements and Recommendations

Remember that courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.

Required Courses: Regenerative Medicine and Engineering		Credits	Can I petition out?
BMD_ENG 343	Biomaterials and Medical Devices	1	No
BMD_ENG 344	Biological Performance of Materials	1	No
MECH_ENG 422	Statistical Mechanics for Applications	1	No
Additional Competency Courses for Regenerative Medicine and Engineering		Credits	Can I petition out?
BIOL_SCI 315	Advanced Cell Biology	1	Petitioning out requires advisor approval before DGS approval (two approvals needed).
<b>Courses required for the coursework component of PhD Candidacy. Take two of the following. You must receive a grade of A- or better in both courses. Otherwise, you must pass a written qualifying exam for the course(s) in which a grade lower than an A- was received.</b>			
		Credits	Can I petition out?
BMD_ENG 346	Tissue Engineering	1	No
BMD_ENG 444	Organic Nanomaterials	1	No
BMD_ENG 347*	Foundations of Regenerative Engineering	1	No
BMD_ENG 348*	Applications of Regenerative Engineering	1	No
*if you take both BMD_ENG 347 and 348, only one of them can be used for the A- requirement			

### Additional Courses Relevant to Regenerative Medicine and Engineering

These are suggestions that are not required but may be of interest.

BMD\_ENG 314 (Models of Biochemistry and Molecular Biology)  
 BMD\_ENG 316 (Engineering Design of Therapeutic Antibodies)  
 BMD\_ENG 325 (Introduction to Medical Imaging)  
 BMD\_ENG 333 (Modern Optical Microscopy and Imaging)  
 BMD\_ENG 365 (Control of Human Limbs and Their Artificial Replacements)  
 BMD\_ENG 366 (Biomechanics of Movement)  
 BMD\_ENG 377 (Intermediate Fluid Mechanics)  
 BMD\_ENG 452 (Transport through Connective Tissues)  
 BMD\_ENG 463 (Systems Neuropathophysiology)

BMD\_ENG 448 (Cardiovascular Biology and Engineering)  
 BMD\_ENG 478 (Advanced Mass and Heat Transfer)  
 BIOL\_SCI 301 (Principles of Biochemistry)  
 BIOL\_SCI 323 (Bioinformatics: Sequence and Structure Analysis)  
 BIOL\_SCI 390 (Advanced Molecular Biology)  
 BIOL\_SCI 391 (Development and Evolution of Body Plans)  
 ELEC\_ENG 495 (Cardiovascular Instrumentation)  
 IEMS 304 (Statistical Learning for Data Analysis)  
 IGP 460 (Cellular and Molecular Aspects of the Cytoskeleton)

## Neural Engineering Track Requirements and Recommendations

Remember that courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.

Required Courses: Neural Engineering Track				
Take at least one of these courses			Credits	Can I petition out?
ES_APPM 370	Introduction to Computational Neuroscience		1	No
COMP_SCI 349	Machine Learning		1	No
ELEC_ENG 435	Deep Learning Foundations from Scratch		1	No
ELEC_ENG 4** or COMP_SCI 4**	With approval from DGS, any 400 level EE or CS course related to machine learning		1	No
Additional Competency Courses for Neural Engineering			Credits	Can I petition out?
NUIN 440	Advanced Neuroanatomy		1	Yes, but petitioning out requires advisor approval before DGS approval (two approvals needed).
ELEC_ENG 359	Digital Signal Processing		1	
MECH_ENG 390	Introduction to Dynamic Systems		1	
Courses required for coursework component of PhD Candidacy. Take two of the following. You must receive a grade of A- or better in both courses. Otherwise, you must pass a written qualifying exam for the course(s) in which a grade lower than an A- was received.				
			Credits	Can I petition out?
BMD_ENG 462	Sensory Acquisition		1	No
BMD_ENG 468	Comp. Neuromechanics & Neuroethology		1	No
BMD_ENG 463	Systems Neuropathophysiology		1	No
BMD_ENG 469	Neural Control and Mechanics of Movement		1	No

### Additional Courses Relevant to Neural Engineering

These are suggestions that are not required but may be of interest.

BMD\_ENG 323 (Visual Engineering Science)

BMD\_ENG 343 (Biomaterials and Medical Devices)

BMD\_ENG 346 (Tissue Engineering)

BMD\_ENG 365 (Control of Human Limbs and their Artificial Replacements)

BMD\_ENG 465 (Biomechanical Modeling and Computer Simulation of Human Movement)

BMD\_ENG 467 (Biomedical Robotics)

MECH\_ENG 314 (Theory of Machines - Dynamics)

EECS 360 (Introduction to Feedback Systems)

MECH\_ENG 333 (Introduction to Mechatronics)

MECH\_ENG 433 (Advanced Mechatronics)

MECH\_ENG 381 (Introduction to Micro-Electro-Mechanical Systems)

MECH\_ENG 451 (Micromachining)

NUIN 480 (Neural Control of Movement)

NUIN 433 (Neurobiology of Disease)

## Rehabilitation Track Requirements and Recommendations

Remember that courses that have a business focus, even if offered in an engineering or basic science department, will **not count** towards the PhD.

Required Courses: Rehabilitation Track				
Take at least one of these courses			Credits	Can I petition out?
BMD_ENG 366	Biomechanics of Movement		1	No
IEMS 315	Stochastic Models		1	No
ELEC_ENG 435	Deep Learning Foundations from Scratch		1	No
COMP_SCI 349	Machine Learning		1	No
Additional Competency Courses for Rehabilitation			Credits	Can I petition out?
NUIN 440	Advanced Neuroanatomy		1	Yes, but petitioning out requires advisor approval before DGS approval (two approvals needed).
MECH_ENG 390	Introduction to Dynamic Systems		1	
<b>Courses required for coursework component of PhD Candidacy. Take one course in each of the two sections below. You must receive a grade of A- or better in both courses. Otherwise, you must pass a written qualifying exam for the course(s) in which a grade lower than an A- was received.</b>				
Take one of the following			Credits	Can I petition out?
BMD_ENG 463	Systems Neuropathophysiology		1	No
BMD_ENG 469	Neural Control and Mechanics of Movement		1	No
Take one of the following			Credits	Can I petition out?
MECH_ENG 314	Theory of Machines -- Dynamics		1	No
ELEC_ENG 390	Intro to Robotics		1	No

### Additional Courses Relevant to Rehabilitation

These are suggestions that are not required but may be of interest.

BMD\_ENG 365 (Control of Human Limbs and their Artificial Replacements)  
 BMD\_ENG 465 (Biomechanical Modeling and Computer Simulation of Human Movement)  
 BMD\_ENG 467 (Biomedical Robotics)  
 COMP\_SCI 330 (Human Computer Interaction)  
 ELEC\_ENG 332 (Introduction to Computer Vision)  
 MECH\_ENG 333 (Introduction to Mechatronics)

MECH\_ENG 433 (Advanced Mechatronics)  
 EECS 360 (Introduction to Feedback Systems)  
 MECH\_ENG 381 (Introduction to Micro-Electro-Mechanical Systems)  
 MECH\_ENG 451 (Micromachining)  
 NUIN 433 (Neurobiology of Disease)  
 NUIN 480 (Neural Control of Movement)