Bioengineering, Ph.D.

COLLEGE OF ENGINEERING

Learn more about the Doctor of Philosophy in Bioengineering.

About the Program

The Ph.D. in Bioengineering addresses the needs of an aging population that is likely to require more medical care and to take advantage of the advances in and benefits of biomedical engineering. Employment of biomedical engineers is projected to grow 27 percent from 2012 to 2022, much faster than the average for all occupations. The Bioengineering Ph.D. program is designed to educate and train doctoral-level bioengineers to work in academic, medical, or industrial settings.

Time Limit for Degree Completion: 7 years

Campus Location: Main, Health Sciences Center

Full-Time/Part-Time Status: Students are able to complete the didactic portion of the Ph.D. degree program through classes offered after 4:30 p.m.

Interdisciplinary Study: Bioengineering research is highly interdisciplinary and draws on collaboration with members of the faculty and students within all departments of the College of Engineering; other departments on Main campus, including Biology, Chemistry, and Kinesiology; and other schools and colleges at Temple University, such as the Kornberg School of Dentistry, Lewis Katz School of Medicine, and School of Pharmacy.

Areas of Specialization: While the Bioengineering Ph.D. is inherently interdisciplinary, the student is admitted to the program and then conducts doctoral research within an area of specialization. These include:

- Biomaterials
- Imaging and Optical Spectroscopy
- Injury Biomechanics
- Neuroengineering
- Neuromechanics of Locomotion
- Regenerative Tissue Engineering
- Stem and Cancer Cell Engineering
- Targeted Drug Delivery

In the first term, the student and the Bioengineering (BIO) Graduate Program Director jointly initiate a Plan of Study. This form lists all required courses and the program requirement sequence for the student to follow. The Plan of Study is used to track the student's progress, with an annual annotation and update as the student completes various benchmarks in the Ph.D. program.

Job Prospects: The program is primarily intended for individuals who wish to pursue careers in industry, government, and academia in a highly creative environment. The program is dedicated to producing engineers who will contribute to advancements in biotechnology.

Non-Matriculated Student Policy: Up to 9 credits of graduate Engineering coursework may be taken at Temple University on a non-matriculated basis and subsequently applied to the Ph.D. degree upon admission. If the applicant's undergraduate GPA was less than 3.0, a GPA of 3.25 or better is required on this non-matriculated graduate coursework to receive an admissions exception. Consequently, the BIO Graduate Program Director may encourage those with an undergraduate GPA less than 3.0 to take their first three graduate courses prior to making formal application to the Ph.D. program. (See the relevant Graduate School policies on special admission procedures for non-matriculated students: 02.23.11.03 and 02.24.19.)

Financing Opportunities: Applicants for full-time study in the Bioengineering Ph.D. program are automatically considered for financial aid. Three forms of financial aid are awarded to Ph.D. students on a competitive basis:

1. Teaching Assistantship (TA): TA awards are made solely by the Department and require the awardee to work 20 hours per week in support of the Department's undergraduate programs. The TA is compensated with a 9-month stipend, a basic health-insurance plan, and 9 credits per term of tuition remission.

2. Research Assistantship (RA): Individual faculty confer RA awards, using their research funds, upon students who appear well-qualified to carry out the research. Typically, this faculty member becomes the RA's doctoral advisor. The RA normally works up to 20 hours per week and is compensated with a stipend, basic health insurance, and tuition remission.

3. Fellowships: Fellowships are awarded by the University in a competitive process that is open to all Ph.D. applicants. The BIO Graduate Program Director nominates exceptional Ph.D. applicants for a University Fellowship. Fellows receive 9 to 12 months of stipend, depending on the award; basic health insurance; and 12 credits of tuition remission each Fall and Spring term. Fellows of the University have no work obligations with respect to either the Department, the College, or the University.
Because financial aid is awarded on a competitive basis, applicants are urged to complete the application as early as possible.

**Admission Requirements and Deadlines**

**Application Deadline:**

*Fall:* March 1  
*Spring:* November 1; August 1 international

Applications are processed on a continual basis. Ordinarily, the applicant is informed of an admissions decision within 4 to 6 weeks of receipt of all supporting application documents.

Both admissions and financial aid award decisions originate in the Bioengineering Department within the College of Engineering. Applicants who plan to matriculate full-time are automatically considered for financial aid awards so no separate application for financial aid is required. To ensure financial aid consideration for the intended term of study, however, applicants should submit a complete application by January 15 (Fall) and August 1 (Spring).

**APPLY ONLINE to this graduate program.**

**Letters of Reference:**

**Number Required:** 3

**From Whom:** Letters of recommendation should be obtained from college or research faculty who are familiar with the applicant's competency. If the applicant has an established career in engineering, one of the letters should be provided by the applicant's immediate supervisor. If the applicant has been out of school long enough that relevant academic reference letters appear impractical, s/he should contact the BIO Graduate Program Director to obtain a waiver of this admission requirement.

**Coursework Required for Admission Consideration:** Students not adequately prepared for advanced courses may be required to take a number of prerequisites. The Bioengineering Department identifies the needed coursework on a case-by-case basis.

**Master's Degree in Discipline/Related Discipline:** A master's degree is not required, but preferred.

**Bachelor's Degree in Discipline/Related Discipline:** A bachelor's degree is required.

University regulations stipulate that the applicant must have earned a 3.0 grade-point average on a 4.0 scale in her/his undergraduate studies, but admission exceptions are made for a variety of circumstances. (See Graduate School Policy 02.23.11.03.) The BIO Graduate Program Director helps the applicant navigate the admission possibilities and assists in the assessment of her/his overall educational qualifications with respect to the departmental requirements for the Ph.D. program.

**Statement of Goals:** Describe your relevant technical experiences, career goals, and specific research interests in one to two pages.

**Standardized Test Scores:**

GRE: Required. Scores must be no more than 5 years in advance of the application date. (See Graduate School Policy 02.23.12.) Applicants who require a waiver of the GRE should consult the BIO Graduate Program Director concerning the mechanics and consequences of obtaining an exception.

Applicants who earned their baccalaureate degree from an institution where the language of instruction was other than English, with the exception of those who subsequently earned a master's degree at a U.S. institution, must report scores for a standardized test of English that meet these minimums:

- TOEFL iBT: 79
- IELTS Academic: 6.5
- PTE Academic: 53

**Resume:** Current resume required.

**Advanced Standing:** Both transfer credit for courses taken at another institution while matriculated at Temple and/or advanced standing credit for courses taken within the 5-year period prior to matriculating at Temple may be applied toward the Ph.D.-level didactic coursework requirement. Written approval is required from the student’s doctoral advisor, the College’s Associate Dean for Graduate Study, and the Graduate School. (See Graduate School Policy 02.24.21.) Up to six credits of advanced standing for courses taken within the 5-year period prior to matriculating at Temple may be used to satisfy the master’s-level didactic coursework requirement. Approval of the BIO Graduate Program Director is required. The courses must be equivalent to courses offered at Temple in the student's area of study and research, and the grades must be 'B' or better.

**Program Requirements**

**General Program Requirements:**
**Number of Credits Required Beyond the Bachelor's:** 60, including 45 credits of graduate-level didactic coursework and 15 research credits, including preliminary Ph.D. examination and dissertation research

**Number of Credits Required Beyond the Master's:** 30, including 15 credits of graduate-level didactic coursework and 15 research credits, including preliminary Ph.D. examination and dissertation research

**Required Courses:**

**Post-Baccalaureate (for students WITHOUT a master's degree in Bioengineering)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Core Courses</td>
<td></td>
</tr>
<tr>
<td>BIOE 5600</td>
<td>Bioengineering Graduate Seminar 1</td>
<td>0</td>
</tr>
<tr>
<td>ENGR 5011</td>
<td>Engineering Mathematics I</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Specialty Courses</td>
<td></td>
</tr>
<tr>
<td>Select three from the following:</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>BIOL 5312</td>
<td>Biostatistics</td>
<td></td>
</tr>
<tr>
<td>BIOE 5719</td>
<td>Introduction to Bioengineering</td>
<td></td>
</tr>
<tr>
<td>BIOE 5721</td>
<td>Cell Biology for Engineers</td>
<td></td>
</tr>
<tr>
<td>BIOE 5737</td>
<td>Systems Physiology for Engineers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technical Electives 2</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Research Courses 3</td>
<td>15</td>
</tr>
<tr>
<td>BIOE 9991</td>
<td>Directed Research (8 credits)</td>
<td></td>
</tr>
<tr>
<td>BIOE 9994</td>
<td>BioEngineering Preliminary Examination Preparation (1 credit)</td>
<td></td>
</tr>
<tr>
<td>BIOE 9998</td>
<td>Bioengineering Pre-Dissertation Research (3 credits)</td>
<td></td>
</tr>
<tr>
<td>BIOE 9999</td>
<td>BioEngineering Dissertation Research (3 credits)</td>
<td></td>
</tr>
</tbody>
</table>

**Total Credit Hours** 60

1. BIOE 5600 Bioengineering Graduate Seminar is required to be taken each academic term while completing the degree.
2. Students who wish to take graduate coursework outside the College of Engineering in one of Temple University's other schools/colleges need to obtain the appropriate written approvals on their Plan of Study form.
3. Expected distribution of the 15 credits associated with Ph.D. examinations and dissertation research is shown, although the actual distribution of credits can vary across courses depending on the student's particular circumstances.

**Post-Master's (for students WITH a master's degree in Bioengineering)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Core Courses</td>
<td></td>
</tr>
<tr>
<td>BIOE 5600</td>
<td>Bioengineering Graduate Seminar 1</td>
<td>0</td>
</tr>
<tr>
<td>ENGR 5011</td>
<td>Engineering Mathematics I</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Specialty Courses</td>
<td></td>
</tr>
<tr>
<td>Select three from the following:</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>BIOL 5312</td>
<td>Biostatistics</td>
<td></td>
</tr>
<tr>
<td>BIOE 5719</td>
<td>Introduction to Bioengineering</td>
<td></td>
</tr>
<tr>
<td>BIOE 5721</td>
<td>Cell Biology for Engineers</td>
<td></td>
</tr>
<tr>
<td>BIOE 5737</td>
<td>Systems Physiology for Engineers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technical Electives 2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Research Courses 3</td>
<td>15</td>
</tr>
<tr>
<td>BIOE 9991</td>
<td>Directed Research (8 credits)</td>
<td></td>
</tr>
<tr>
<td>BIOE 9994</td>
<td>BioEngineering Preliminary Examination Preparation (1 credit)</td>
<td></td>
</tr>
<tr>
<td>BIOE 9998</td>
<td>Bioengineering Pre-Dissertation Research (3 credits)</td>
<td></td>
</tr>
<tr>
<td>BIOE 9999</td>
<td>BioEngineering Dissertation Research (3 credits)</td>
<td></td>
</tr>
</tbody>
</table>

**Total Credit Hours** 30
BIOE 5600 Bioengineering Graduate Seminar is required to be taken each academic term while completing the degree.

Students who wish to take graduate coursework outside the College of Engineering in one of Temple University's other schools/colleges need to obtain the appropriate written approvals on their Plan of Study form.

Expected distribution of the 15 credits associated with Ph.D. examinations and dissertation research is shown, although the actual distribution of credits can vary across courses depending on the student's particular circumstances.

Culminating Events:

Formation of the Doctoral Advisory Committee:
Selection of a research advisor and formation of a Doctoral Advisory Committee constitute the first steps toward achieving a Ph.D. Selection of a doctoral advisor depends on the student’s level of preparation upon entering the Ph.D. program. The Doctoral Advisory Committee selects the required coursework and guides the progress of the student’s dissertation research:

- Students entering the Ph.D. program with a master's degree, i.e., those who must complete 30 credits to earn the degree, form their Doctoral Advisory Committee before the end of their second regular term of study.
- Students entering the program with a bachelor's degree, i.e., those who must complete 60 credits to earn the Ph.D. degree, generally complete most of their coursework before forming their Doctoral Advisory Committee by the end of their fourth regular term in the program.

See Graduate School Policy 02.28.11 for clarification on the composition of the Doctoral Advisory Committee.

Preliminary Examination:
All students generally complete their didactic coursework prior to taking the preliminary examination. (See Graduate School Policy 02.27.11.) Students in the 30-credit cohort ordinarily take the exam in their third or fourth term. Students in the 60-credit cohort typically take the exam no later than the eighth regular term. Students should register for one credit of BIOE 9994 BioEngineering Preliminary Examination Preparation in the term when the exam will be taken.

The preliminary exam tests both the student's core knowledge in Bioengineering and her/his capacity to synthesize and interpret research communications. The student coordinates the scheduling of the preliminary exam with the BIO Graduate Program Director. The BIO Graduate Program Director supervises the specific form, content, and frequency of the Bioengineering preliminary exam. A maximum of two opportunities to pass the preliminary exam are available to the student. In each term when the exam is attempted, the student registers for one credit of BIOE 9994. Students are dismissed upon the second failure.

Dissertation Proposal:
Within a year of passing the preliminary exam, the student must develop a written research proposal and present it in an open College seminar. Ten business days prior to the presentation seminar, the student must schedule the proposal and post an announcement. Immediately following the seminar, the Doctoral Advisory Committee questions the student about the details and strategy of her/his proposed research.

Approval is granted for the proposed dissertation research when the 'Dissertation Proposal Transmittal for Elevation to Candidacy' form (found in TUportal under the Tools tab within "University Forms") has been signed off by the entire Doctoral Advisory Committee. After the dissertation proposal has been accepted by the Doctoral Advisory Committee and the Graduate School has received the form, the student is considered to be a doctoral candidate. (See Graduate School Policy 02.28.12 for more information.)

Research Credits:
Students carry out research throughout their studies and register for the corresponding research credits while in the Ph.D. program. However, the type of research credits that a student registers for depends on the student's progress in the program:

- Prior to passing the preliminary exam, credit hours associated with the student’s research should be registered under BIOE 9991 Directed Research.
- After the preliminary exam is passed, but before elevation to candidacy, credit hours associated with the student’s research should be registered under BIOE 9998 Bioengineering Pre-Dissertation Research.
- After elevation to candidacy, the student’s research credits should be registered under BIOE 9999 BioEngineering Dissertation Research. Students are required to register for at least three credits of BIOE 9999 following their elevation to candidacy. (See Graduate School Policy 02.28.15.)

Publications:
Paper writing and presentation at a conference are considered integral to the student's training. Also, peer review, in part, offers an indication of the quality and novelty of the student's research. All doctoral students must publish at least two technical papers in refereed journals or refereed conferences. The papers must be based on the student's dissertation research with the student as the first author.

Dissertation:
The dissertation defense is an open University seminar in which the student presents the concepts and results of her/his research.

The student must coordinate the formation of the Dissertation Examining Committee in the term that s/he intends to defend her/his dissertation. This committee consists of the original Doctoral Advisory Committee plus one additional “external” member who is not faculty in the College of Engineering. If the external examiner is not a member of Temple University’s Graduate Faculty, the person must be approved by the Graduate School at least four weeks prior to the dissertation defense.
The dissertation defense is to take place during a regular academic term (i.e., not scheduled during study days, final exams, or the breaks between terms). If the student is to graduate in the same term as the dissertation defense is held, then the defense should take place at least 30 days prior to the end of the term to allow for document revisions.

Three weeks prior to the defense, the members of the committee elect a Chair of the Dissertation Examining Committee. The Chair cannot be the student’s doctoral advisor. The Associate Dean of Research and Graduate Studies must approve the selection. The Chair is identified to the Graduate School in the student’s official request for permission to schedule the defense. (See Graduate School Policy 02.28.15.) The Chair’s role includes coordination of the proceedings of the defense and completion of all relevant College and Graduate School forms concerning the defense.

The dissertation document should be prepared in a format compliant with University standards. (See Graduate School Policy 02.28.18.) A copy of the completed dissertation must be provided to the committee at least three weeks before the date of the dissertation defense. Note that any Graduate Faculty may request a copy of the dissertation in advance of the defense and may participate in the defense.

A minimum of two weeks prior to the defense, a public announcement of the defense must be posted. Prior to posting, this announcement must be approved in writing by the Graduate School. (See Graduate School Policy 02.28.16.)

Immediately following the presentation, the Dissertation Examining Committee closely examines the student’s performance and her/his research. External attendees may participate in this closed portion of the defense with the permission of the Dissertation Examining Committee Chair. However, only members of the Dissertation Examining Committee may actually vote on the decision to accept the dissertation as prepared, accept the dissertation with revisions, or not accept the dissertation. If the dissertation is accepted with revisions, a revised copy of the dissertation must be submitted and approved by the Committee within 30 days of the original defense date.

Contacts

Program Web Address:
https://www.temple.edu/academics/degree-programs/bioengineering-phd-en-bioe-phd

Department Information:

College of Engineering
ATTN: BIO Programs
1947 N. 12th Street
Philadelphia, PA 19122-6077
gradengr@temple.edu
215-204-7800

Submission Address for Application Materials:
https://apply.temple.edu/Engineering/

Department Contacts:

Admissions:
Colleen P. Baillie, Ed.D.
colleenb@temple.edu
215-204-7800

Graduate Program Director, BIO:
Yah-el Har-el, Ph.D.
yahel@temple.edu
215-204-3426

Chairperson, BIO:
Peter Lelkes, Ph.D.
pilelkes@temple.edu
215-204-3307
Bioengineering Courses

**BIOE 5301. Biosignals. 3 Credit Hours.**
This course offers a deep overview of the signals in the Biomedical fields. Signals are studied in several modalities, including time frame, frequency frame, and statistical frame. A deep analysis of filters and analysis tools is included together with some basic techniques of storing and pattern interpretation techniques. Furthermore, the course gives to the student the necessary knowledge to realize a complete Data Acquisition, Analysis and Logging using LabView as a tool. The laboratory activities include the development of a complete system to do acquisition, analysis, report and logging of data incoming from sensors.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5311. The Entrepreneurial Bioengineer. 3 Credit Hours.**
This course provides a practical overview of all stages of development of medical devices in regenerative medicine, from idea to launch of a company and commercialization of the product into international markets to address unmet medical needs. We will review the initial idea, based on an unmet medical need, review issues of intellectual property creation, determination of target markets, pre-clinical and clinical development, and different regulatory pathways leading to product approval and market introduction. We will discuss issues of company formation, financing and management, as well as target markets and avenues towards revenue generation. Note: Prior to fall 2017, the course title was 'Entrepreneurial Studies in Regenerative Medicine - From Idea to Medical Practice'.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5321. Biosensors. 3 Credit Hours.**
This course offers an in-depth overview of several sensors used in the Biomedical Fields. The sensors are analyzed from an engineering point of view going from the physical principles to the necessary filtering and linearization studying the characteristics of output signals. The course also gives the student the necessary basis for Data Acquisition using LabView as a tool. The laboratory activities include the connection of sensors, the study of amplification, linearization and interpretation of data.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5333. Applied Biospectroscopy. 3 Credit Hours.**
This course introduces the basics of light propagation in tissue and other turbid media, vibrational spectroscopy, absorption and fluorescence, and emerging spectroscopic applications. Emphasis is on applications for assessment of biomolecules, engineered tissues and clinically-relevant analyses including musculoskeletal disease and cancer diagnosis. Multivariate analyses for complex spectral data sets will also be introduced.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5421. Capstone Elective: Bionanotechnology. 3 Credit Hours.**
This course is intended for graduate students interested in acquiring knowledge involving nanometer-sized objects frequently utilized within the biomedical sciences and engineering areas. The aim of the class is to introduce fundamental concepts critical in the design, preparation, analysis, and usage of bionanotechnology (or nanobiotechnology) and its multiple bottom-up and top-down approaches. Multiple nanomaterials categories, such as nanoparticles, nanotubes, biomacromolecules, synthetic polymers, and self-assembled structures, will be covered in detail along with their applications.

**Field of Study Restrictions:** Must be enrolled in one of the following Majors: Bioengineering.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.
**BIOE 5431. Neuroengineering. 3 Credit Hours.**
This course will teach students how signals are generated and propagated in neurons and neuronal circuits, and how this knowledge can be utilized to engineer devices to assist people with neurologic disease or injury. The functions of neurons as discrete elements and as parts of neuronal assemblies will be examined; generator and action potentials; conduction in nerve fibers and across synaptic junctions; analysis of sensory and neuromuscular systems; EEG and EKG waveforms. At the completion of the course, students will have gained a fundamental understanding of neural interface/prosthetics design parameters from basic neural physiology to models of neural mechanisms. We will also review advanced neural interfaces currently being developed. The course will end with coverage of selected frontiers of neuroscience, including neurogenetic techniques, viral methods, and optogenetics.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5441. Biomechanics. 3 Credit Hours.**
This course will provide an integrative and multi-scale understanding of biomechanics that spans from tissues, to organs, to the dynamics of an intact, running body. Foundational topics will include muscle mechanics, skeletal mechanics, gait and whole body dynamics. The course will then move on to cover selected topics at the forefront of applied biomechanics including clinical biomechanics and the design and optimization of prosthetic limbs. Finally, frontiers in neural-interfacing for prostheses and rehabilitation, including optogenetics and other emerging areas affecting biomechanics, including robotics and robotic exoskeletons, will be covered.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**College Restrictions:** Must be enrolled in one of the following Colleges: Engineering.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5451. Biomedical Imaging. 3 Credit Hours.**
This course focuses on principles of diagnostic radiological imaging physics, including X-ray, computed tomography, and nuclear medicine, as well as optical imaging, ultrasound and magnetic resonance imaging modalities. The interaction of these modalities with tissues and detectors to produce useful image contrast will be presented, and students will gain an understanding of the basic physics of image acquisition and algorithms for image generation. Signal and noise characteristics, image quality and image reconstruction algorithms will also be covered. Image processing through MATLAB programming will be covered in class and in assignments.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5461. Principles of Tissue Engineering. 3 Credit Hours.**
This course will introduce fundamental concepts of tissue engineering and regenerative medicine, focusing biomaterials used for scaffolds, mechanisms of cell-biomaterial interactions, biocompatibility and foreign body response, cellular engineering, and tissue biomechanics. Principles of cell/developmental and stem cell biology will be introduced, which will enable the students to apply a multidisciplinary approach to engineering select tissues and organs, such as the musculoskeletal system, cardiovascular tissues, the nervous system, and to design artificial organs. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns. Note: Prior to fall 2017, the course title was ‘Principles of Tissue and Regenerative Engineering.’

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5500. Special Topics in Bioengineering. 3 Credit Hours.**
An emerging or advanced area of bioengineering research will be covered. Topics vary by semester.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.
BIOE 5501. Regenerative Engineering. 3 Credit Hours.
This course is a continuation of fundamental concepts introduced in Principles of Tissue and Regenerative Engineering focusing on developmental biology used in tissue engineering and regenerative medicine. Principles of cell development/biology, cell-cell interactions, signal transduction, and stem cell biology will be discussed with applications to regenerative medicine. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns.

Field of Study Restrictions: Must be enrolled in one of the following Majors: Bioengineering.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(BIOE 5461|Minimum Grade of B-|May not be taken concurrently)
AND (BIOE 5721|Minimum Grade of B-|May not be taken concurrently)

BIOE 5555. Biophotonics: Seeing is Believing. 3 Credit Hours.
Only a small portion of the world around us is visible to the human eye. So, is there a way to visualize chaos, force, fractals, viral infection or cancer metastasis? Once we see biology happen, is the result a pretty image or a valuable measurement? Can the light be used to modify biological processes? In this course students will learn how photons are used to visualize and manipulate biomaterials at multiple scales. The first part of the course will provide a review of electromagnetism, light and optics. We will cover typical hardware used for imaging in biology, such as light sources, objectives and detectors used to generate images. Next, chemistry of imaging probes will be covered, including photochemistry and interaction of light and matter. The rest of the course will give a comprehensive overview of methodologies for multiscale imaging in life sciences, ranging from electron to atomic-molecular-cell-multicellular tissue-whole body scales, in vitro and in vivo. This will include among others Spectroscopy, Microscopy (Electron, Atomic, Fluorescent), Flow Cytometry, Optical Traps, Bioluminescence, X-Ray, MRI. Final classes will include special demonstrations in the imaging labs in the Temple Main Campus.

Field of Study Restrictions: Must be enrolled in one of the following Fields of study: Bioengineering.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5600. Bioengineering Graduate Seminar. 0 Credit Hours.
Required seminar for bioengineering graduate students. These seminars include speakers from academic and professional backgrounds for both scientific development and professional development. Students will be graded on participation of at least 70% of the bi-weekly seminars throughout the duration of the semester.

Field of Study Restrictions: Must be enrolled in one of the following Majors: Bioengineering.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 5719. Introduction to Bioengineering. 3 Credit Hours.
This course offers an introduction to biomedical engineering, a diverse and evolving field that integrates engineering principles, life sciences, clinical medicine, research and engineering design, with the overall goal of improving health care and quality of life. Professors with expertise in specific fields of biomedical engineering will present lectures and discussions on a broad range of topics, including tissue engineering and regenerative medicine, biomaterials, biomechanics, bioinstrumentation, biomedical imaging and optics, and signal processing.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5721. Cell Biology for Engineers. 3 Credit Hours.
This course introduces biological concepts in modern cellular and molecular biology to engineering students. Topics will include the chemical composition of cells, bioenergetics and metabolism, structure and function of the plasma membrane, transport across membranes, the cytoplasmic membrane system, the extracellular matrix, interactions between cells and their environment, the cytoskeleton and cell motility, sensory systems, and cell signaling. In addition, an introduction to basic anatomy and physiology of vertebrates will include the skeletal system, muscle system, cardiovascular system, and nervous system.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOE 5737. Systems Physiology for Engineers. 3 Credit Hours.
Systems Physiology is designed for graduate students majoring in engineering and for others interested in studying physiological processes from the molecular level to the organ/systems level. Among the topics covered are: scaling, respiration, circulation, cardiac process, renal function, muscle function, neuromuscular junction, neural processes, and temperature regulation. The course stresses the application of energetic and informational principles to the study of the body.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5741. Biomaterials for Engineers. 3 Credit Hours.
This course introduces engineering students to materials as they interact with biological systems, primarily in medicine. Topics will include a review of properties of materials, the classes of materials, tissues that come into contact with materials, the degradation of materials in the biological environment, the application of materials for specific uses, tissue engineering, and biomaterials standards and regulations.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5999. Research Experience in Bioengineering. 0 Credit Hours.
Research Experience provides graduate students laboratory experiences/research practices prior to undertaking independent, directed, master project, master’s thesis, or dissertation research. This course allows graduate students the opportunity to learn to use laboratory equipment, designing and carrying out an experiment(s), collecting preliminary data, field experiences, and participation in laboratory meeting, etc. with faculty which may lead to identifying a faculty mentor. The course will be graded as Pass or Fail. The Research Experience is a non-repeatable course. After the completion of this Research Experience course, students will need to be enrolled in independent study, directed research, master’s research, master’s thesis, dissertation proposal, or dissertation if they continue in an active research program.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 9182. Independent Study. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9991. Directed Research. 1 to 3 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9994. BioEngineering Preliminary Examination Preparation. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9995. BioEngineering Project Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9996. BioEngineering Thesis Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9998. Bioengineering Pre-Dissertation Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
BIOE 9999. BioEngineering Dissertation Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Student Attribute Restrictions: Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.
Repeatability: This course may be repeated for additional credit.

Engineering Courses

ENG 5011. Engineering Mathematics I. 3 Credit Hours.
This is a survey course in essential mathematics for first-year graduate students in engineering and physical sciences. Topics include analytic methods in ordinary differential equations, complex-variable theory, the laplace transform and its inversion, and initial-value problems and boundary-value problems. Matlab, numerical methods, and introductory numerical algorithm design are introduced.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ENG 5012. Engineering Mathematics II. 3 Credit Hours.
This is a survey course in classical numerical and analytical methods for partial differential equations, for first-year masters and doctoral students in engineering and physical sciences. Topics include analytic methods and numerical methods for partial differential equations in cartesian and non-cartesian coordinate systems, and an introduction to perturbation theory. The course will emphasize quantitative analysis, and assignments will entail computational algorithm design.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ENG 5022. Engineering Analysis and Applications. 3 Credit Hours.
Vector space, basis, projection, null space, function space, L2 and space of continuous functions, Hilbert space, orthogonality, generalized Fourier series, linear transformation, adjoint transformation, eigenvalue problem, linear functional, Gateaux and Frechet differential, constrained optimization, infinite dimensional systems, complex analysis.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ENG 5031. Engr Prob Stats Stoc Met. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ENG 5032. Probability, Statistics, and Stochastic Methods. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ENG 5033. Probability and Random Processes. 3 Credit Hours.
Sets and events, Random variables, Distribution and density functions, Functions of multiple random variables, Moments and conditional statistics, Information entropy, stochastic processes, wide-sense stationary process, ergodicity, correlation, and power spectrum of stationary processes. Applications to sampling theory and signal modulation and detection.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ENG 5110. Special Topics. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may be repeated for additional credit.
ENGR 5116. Spacecraft Systems Engineering. 3 Credit Hours.
The concept of systems engineering is introduced using a satellite application. Systems engineering is a top-down approach to the design, implementation, testing, and deployment of large-scale systems to meet the needs of users. The topics will include systems engineering methodology, dynamics of spacecraft, and celestial mechanics. This course will also introduce the notion of invention and innovation, and how they are related to the intellectual property issues.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5117. Experimental Methods. 3 Credit Hours.
Application and design of experimental techniques and measurement systems used in engineering laboratories. Introduction to the DMM, digital scope, and computer-based data acquisition systems for measurements of force, motion, pressure, temperature, and flow in steady and unsteady systems. Data transmission, data analysis and presentation, and computer interfacing techniques. Statistical methods and uncertainty analysis. Hands-on experience with state-of-the-art instrumentation systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5121. Design of Experiments. 3 Credit Hours.
The practice of modern science and engineering is synonymous with the ability to plan, design and conduct experiments efficiently and effectively, and analyze the resulting data to obtain objective conclusions in applications ranging from new product design and development to phenomenological/basic science studies. In this course we will focus primarily on methodological and design issues in planning experiments rather than on statistical analysis of the data. Nevertheless, we will briefly review various statistical analysis approaches required for fully designed experiment. Case studies involving single factor experiments, factorial designs, manipulation checks, etc. will be used to develop hands on skills for designing your own experiments. The course will have a focus on engineering approach to design of experiments with a particular emphasis on problem definition, system identification, data collection, statistical analysis, and hypothesis testing. For the final project, you will prepare a fellowship or grant (e.g. NSF GRFP or AHA Predoctoral) application ready for submission to a funding agency.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5314. Continuum Mechanics. 3 Credit Hours.
This course covers tensors, kinematics of a continuum, stress, integral formulations, linear isotropic elastic solid, and an introduction to Newtonian Fluid (CLO 3).

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5334. Dynamical Systems. 3 Credit Hours.
This course focuses on the algebraic and differential equations governing the static and dynamic 3D motion of 3D bodies, including vectors, vector differentiation, and dyads. The equations of motion for multibody systems will be derived using Newton-Euler, Lagrange, and Kane's methods. Computational tools for 3D force and motion analysis will be used to simulate physical systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5511. Fluid Dynamics. 3 Credit Hours.
Navier-Stoke's equation, Laminar and turbulent flow, boundary layer phenomena, compressible fluid flow including isotropic flow, shock waves, friction flow, and flow with heat transfer.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
ENGR 5576. Computational Fluid Dynamics. 3 Credit Hours.
This course introduces the fundamentals of numerical solution methods for thermal and fluid dynamics applications. Focus is placed on the development of explicit and implicit methods for solving linear and nonlinear partial differential equations for heat conduction, wave propagation, and potential flow. Important topics pertaining to the use of commercial and research grade CFD software are included. As a final course objective, students will develop a solution method for 2D incompressible flow using MATLAB or a similar programming environment.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 8110. Special Topics. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9182. Independent Study I. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by MS/MSE students and once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9185. Experience in Engineering Profession I. 1 to 3 Credit Hour.
This course involves work experience in industry on current industrial practices of advanced engineering concepts under the supervision of a faculty advisor and an industrial mentor. At the end of the internship period, the student submits a technical report that is suitable for general public release. The report is graded by the faculty advisor in consultation with the industrial mentor. Students already employed in the industry are not eligible to register for this course.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9285. Exper Engineer Prof II. 1 to 3 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9990. Engineering Seminar. 1 to 3 Credit Hour.
Students present their research results at an open seminar. The seminars may be arranged on a biweekly basis over the semester. Active participation of all graduate students is expected.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9991. Directed Research. 1 to 6 Credit Hour.
Under the guidance of a faculty member, the student will conduct independent research on a selected topic in engineering.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have completed their coursework but who have not yet passed both the Ph.D. Preliminary Examination.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
ENGR 9995. Project. 1 to 3 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9996. Thesis. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9998. Pre-Dissertation Research. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have passed both the Preliminary and Qualifying Examinations but who have not been elevated to candidacy.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ENGR 9999. Dissertation Research. 1 to 6 Credit Hour.
This course is intended only for those students who have achieved Ph.D. Candidacy status. A minimum of 6 semester hours is required for graduation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Student Attribute Restrictions: Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

Repeatability: This course may be repeated for additional credit.