

Bioengineering, M.S.Bioe.

COLLEGE OF ENGINEERING

Learn more about the Master of Science in Bioengineering.

About the Program

The M.S.Bioe. program offers students graduate-level interdisciplinary education and research opportunities in bioengineering and engineering applications in related healthcare fields. The program offers concentrations in Bioelectronics, Biomaterials, and Biomechanics. Graduates of the program are prepared for careers in industry or may choose to pursue a program of study leading to the Ph.D. degree. The program offers research opportunities in collaboration with faculty in the College of Science and Technology and the Lewis Katz School of Medicine.

Time Limit for Degree Completion: 5 years

Campus Location: Main. Students may also take a significant number of required and elective courses at the Health Sciences Center campus.

Full-Time/Part-Time Status: The degree program can be completed on a full- or part-time basis.

Interdisciplinary Study: The program encourages interdisciplinary research with other branches of engineering as well as with various departments of the College of Science and Technology and the Lewis Katz School of Medicine.

Areas of Specialization: For each of the three areas of specialization, research includes:

- Bioelectronics — sensor development and image analysis.
- Biomaterials — wear of ultra-high molecular weight polyethylene, polymer chemistry, and interfacial chemistry.
- Biomechanics — computer-aided design of composite biomaterials, mechanical properties of orthopedic implant materials, design of orthopedic implants, and modeling of biomaterial behavior.

For the M.S.Bioe. program, students also choose between three tracks:

1. The Thesis Track is intended for students pursuing advanced research and includes 24 credits of didactic coursework, 3 credits of Project (BIOE 9995), and 3 credits of Thesis (BIOE 9996).
2. The Project Track introduces students to applied research and includes 27 credits of didactic coursework and 3 credits of Project (BIOE 9995).
3. The Coursework Track provides students with an advanced engineering background for their future in the engineering profession through 30 credits of didactic coursework.

In the first term, the student and the Bioengineering (BIO) Graduate Program Director establish a graduate Plan of Study that outlines all required courses and the sequence for the student to follow. This form is used to track the student's progress as the various benchmarks in the program are completed. Once established, any revisions to the Plan of Study require approval in advance. However, if considering whether to change one's track, the student should note that:

- "Thesis" credits (BIOE 9996) can only be applied toward the Thesis M.S.Bioe. Track and cannot be applied to either the Project or Coursework Tracks.
- "Project" credits (BIOE 9995) can be applied toward the Thesis and Project M.S.Bioe. Tracks but cannot be used for the Coursework Track.

Job Prospects: Graduates with the M.S.Bioe. degree are employed in a variety of biomedical industries ranging from device manufacturers to design engineering. Other possibilities include careers in government, either in regulatory agencies or with the U.S. Patent and Trademark Office. Students who complete the M.S.Bioe. degree with a thesis are prepared to enter a doctoral program.

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 M.S.Bioe. 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 M.S.Bioe. 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: Three forms of financial aid are offered to graduate students:

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 Bioengineering 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 Thesis 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: These highly competitive University-wide grants are typically awarded only to Ph.D.-program applicants.

Admission Requirements and Deadlines

Application Deadline:

Fall: March 1

Spring: November 1; August 1 international

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

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).**

Both admissions and financial aid award decisions originate in the Bioengineering Department. Applicants are encouraged to contact the BIO Graduate Program Director for advice and consultation in the application process.

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.

Bachelor's Degree in Discipline/Related Discipline: A bachelor's degree in Bioengineering or a related discipline is the preferred prerequisite degree. However, students who have earned a bachelor's degree in a related field are encouraged to apply, with the understanding that remedial preparatory courses may be a pre-condition of admission to the M.S.Bioe. program.

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, including the "Non-Matriculated Student Policy" option.

Statement of Goals: Describe your relevant technical experiences and career goals 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.

Transfer Credit: Graduate credits taken at an accredited institution prior to matriculation may be transferred into the M.S.Bioe. program. In order to transfer, 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. The maximum number of credits a student may transfer is 6. (See Graduate School Policy 02.24.21.)

Test Waivers: Applicants with two or more years of employment in an engineering profession performing engineering design and analysis may request a waiver of the GRE. Consult with the BIO Graduate Program Director concerning the mechanics and consequences of obtaining an exception.

Program Requirements

General Program Requirements:

Number of Credits Required Beyond the Baccalaureate: 30

Required Courses:

Thesis Track

Code	Title	Credit Hours
Core Courses		
BIOE 5600	Bioengineering Graduate Seminar ¹	0
ENGR 5011	Engineering Mathematics I	3
Specialty Courses		
Select three from the following:		9
BIOE 5312	Biostatistics	
BIOE 5719	Introduction to Bioengineering	
BIOE 5721	Cell Biology for Engineers	
BIOE 5737	Systems Physiology for Engineers	
Electives ²		12
Research Courses		
BIOE 9995	BioEngineering Project Research	3
BIOE 9996	BioEngineering Thesis Research	3
Total Credit Hours		30

¹ BIOE 5600 Bioengineering Graduate Seminar is required to be taken each academic term while completing the degree.

² Coursework may include up to, but no more than, 3 credits of ENGR 9182 Independent Study I or 3 credits of BIOE 9991 Directed Research. Furthermore, 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.

Project Track

Code	Title	Credit Hours
Core Courses		
BIOE 5600	Bioengineering Graduate Seminar ¹	0
ENGR 5011	Engineering Mathematics I	3
Specialty Courses		
Select three from the following:		9
BIOE 5312	Biostatistics	
BIOE 5719	Introduction to Bioengineering	
BIOE 5721	Cell Biology for Engineers	
BIOE 5737	Systems Physiology for Engineers	
Electives ²		15
Research Course		
BIOE 9995	BioEngineering Project Research	3
Total Credit Hours		30

¹ BIOE 5600 Bioengineering Graduate Seminar is required to be taken each academic term while completing the degree.

² Coursework may include up to, but no more than, 3 credits of ENGR 9182 Independent Study I or 3 credits of BIOE 9991 Directed Research. Furthermore, 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.

Coursework Track

Code	Title	Credit Hours
Core Courses		
BIOE 5600	Bioengineering Graduate Seminar ¹	0
ENGR 5011	Engineering Mathematics I	3
Specialty Courses		
Select three from the following:		9
BIOE 5312	Biostatistics	
BIOE 5719	Introduction to Bioengineering	
BIOE 5721	Cell Biology for Engineers	
BIOE 5737	Systems Physiology for Engineers	
Electives ²		18
Total Credit Hours		30

¹ BIOE 5600 Bioengineering Graduate Seminar is required to be taken each academic term while completing the degree.

² Coursework may include up to, but no more than, 3 credits of ENGR 9182 Independent Study I or 3 credits of BIOE 9991 Directed Research. Furthermore, 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.

Culminating Events:

Thesis Track:

The culminating events in the Thesis Track are typically undertaken during the last two successive terms of study. Successful completion requires the following:

- Thesis Proposal — BIOE 9995 BioEngineering Project Research (3 credits)
Under the guidance of the advisor, the student conducts independent research on an applied engineering topic of current interest and registers for BIOE 9995. This work includes the research and preliminary results that form the basis of an extended study that the student plans to carry on in BIOE 9996 BioEngineering Thesis Research in the following term. The student submits a research report as her/his Thesis Proposal to a committee consisting of three or more faculty members, including the faculty advisor, and presents her/his proposal in an open College-wide seminar, which is scheduled and posted at least 10 business days in advance of the presentation date. Immediately following the presentation, the student's advisory committee questions the student about the details and strategy of the proposed research. The committee then accepts, accepts with revisions, or rejects the proposal.
The student must pass the Thesis Proposal before registering for BIOE 9996. If the student fails Thesis Proposal, s/he may either re-register for BIOE 9995 (1 credit) in the next regular term and repeat the entire proposal process or consider switching to the Project or Coursework Track.
NOTE: A second failure of Thesis Proposal results in automatic dismissal from the University. If switching to another track, the Plan of Study form requires updating and appropriate approvals.
- Thesis Defense — BIOE 9996 BioEngineering Thesis Research (3 credits)
The student should register for BIOE 9996 in the term that s/he plans to defend the thesis. The thesis document should be prepared in a format compliant with University standards. (See Graduate School Policy 02.26.12.02.) Two weeks prior to the thesis defense, the student provides the committee with a copy of the completed thesis and posts an announcement of the defense, which 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 thesis defense is held, then the defense should take place at least 30 days prior to the end of the term.
The thesis defense is an open College seminar in which the student presents the concepts and results of her/his research. Immediately following the defense, the thesis committee convenes to closely examine the student's research and decide to accept the thesis as provided, accept the thesis with revisions, or not accept the thesis. If the thesis is accepted, a letter grade for BIOE 9996 is assigned. If the thesis is accepted with revisions, then the student must submit the revised thesis within 30 days and with the approval of the Thesis Committee. If the thesis is not accepted, but the committee decides to not fail the student, an "R" grade is assigned to BIOE 9996. In the following term, the student registers for one credit of ENGR 9991 Directed Research until s/he is again prepared to attempt the defense. The defense procedures described above are then carried out again in the term that the student is prepared to defend the thesis.

Project Track:

The culminating event for the Project Track is BIOE 9995 BioEngineering Project Research. This entails a one-term research activity done under the supervision of a full-time faculty advisor on an applied engineering topic of interest. Near the end of the term, the student prepares a report of her/his findings and presents the study in an open departmental seminar. Both the seminar and the written report are used to determine the student's grade for BIOE 9995. The grade is determined jointly by the advisor and another designated grader selected by the Graduate Program Director.

Coursework Track:

Successful completion of coursework constitutes the culminating event.

Contacts

Program Web Address:

<https://www.temple.edu/academics/degree-programs/bioengineering-ms-en-bioe-msbe>

Department Information:

Bioengineering Department
ATTN: BIO Programs, College of Engineering
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:

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Graduate Program Director, BIO:

Yah-el Har-el, Ph.D.
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Chairperson, BIO:

Peter Lelkes, Ph.D.
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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 on 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

ENGR 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.

ENGR 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.

ENGR 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.

ENGR 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.

ENGR 5032. Probability, Statistics, and Stochastic Methods. 3 Credit Hours.

A balanced approach to probability, statistics, stochastic models, and stochastic differential equations with special emphasis on engineering applications. Random variables, probability distributions, Monte Carlo simulations models, statistical inference theory, design of engineering experiments, reliability and risk assessment, fitting data to probability distributions, ANOVA, stochastic processes, Brownian motion, white noise, random walk, colored noise processes. Differential equations subject to random initial conditions, random forcing functions, and random parameters. Partial differential equations subject to stochastic boundary conditions. New techniques for non-linear differential equations. Computer simulation with MAPLE and other symbolic algebra software.

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

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

ENGR 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.

ENGR 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.