# Biomedical Engineering

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The mission of the Department of Biomedical Engineering is to bridge engineering, science and medicine:
- to educate and train the next diverse generation of biomedical engineers
- to conduct research leading to significant discoveries in medical sciences
- to conduct design and development of innovative medical technology
- to translate scientific discovery and medical technology to industry or clinical practice for delivery of health care
- to engage with the local to global community for knowledge dissemination

The objectives of the graduate Biomedical Engineering Program at FIU are the following:
1. Provide opportunity for advanced graduate studies and entrepreneurial activities;
2. Encourage FIU graduates to extend their careers into research and teaching;
3. Prepare graduates for conducting innovative and impactful biomedical engineering research, design and development;
4. Provide highly trained professionals in Biomedical Engineering to serve in academic institutions, government agencies, research laboratories, and manufacturing and service industries.
5. Improve minority and hispanic doctoral graduate representation in the Biomedical Engineering field, where they are highly underrepresented; and
6. Help attract more biotechnology industries to Miami-Dade County and South Florida.

## Master of Science in Biomedical Engineering

The Department of Biomedical Engineering at Florida International University offers Research and Professional tracks for the Master's Degree. In addition, the Department offers accelerated combined BS/MS and certificate programs. These programs provide an interdisciplinary education intended to prepare the student for professional practice in Biomedical Engineering.

All work counted for the Master's degree must be completed during the six years immediately following the date of admission to the graduate program.

**Admission Requirements**

The following is in addition to the University's graduate admission requirements:
1. A student seeking admission into the program must have a bachelor's degree in engineering, the physical/life sciences, computer science, or mathematics from an accredited institution, or in the case of foreign students, from an institution recognized in its own country as preparing students for further study at the graduate level.
2. An applicant must have achieved a "B" average in upper level undergraduate work. Graduate Record Examination is required with the following minimum scores on the individual components: verbal ≥ 143, and quantitative ≥ 151.
3. Applicants who have not satisfied the above will be evaluated for probationary or waiver admission.
4. In addition to the above criteria, International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of 80 on the iBT TOEFL or 6.5 overall on the IELTS is required.
5. The GPA, GRE, and TOEFL scores specified above are to be considered minimum requirements for admission. Applicants from science and engineering areas other than biomedical engineering will be expected to complete undergraduate remedial courses selected to prepare them for graduate courses in their area of interest. Full admission into the graduate program requires the completion of these background courses with no grades below "C" and a grade point average of 3.0 or better.

**Graduation Requirements**

The degree will be conferred when the following conditions have been met:
1. Recommendation of the advisor and faculty of the Department.
2. Certification provided by the Department Chair, College Dean, and University Graduate School that all degree requirements have been met.
3. Meet the undergraduate deficiencies, if any existed in the student's program, as additional courses toward the degree.
4. Complete the required semester hours of graduate level credit (not more than six graduate semester hours with a grade of "B" or higher can be transferred from other accredited institutions).
5. Successful defense of an acceptable graduate thesis if required of the program.
6. Students must maintain an overall GPA of 3.0. No grade below a "C" will be accepted in a graduate program. In the event that a student is placed on probationary status, he or she must obtain a directed program from his or her advisor and approved by the Graduate Program Director prior to continuing further course work toward the degree. The student must satisfy the directed course of action within the prescribed time limit; otherwise he or she will be academically dismissed.
7. Comply with all University policies and regulations.

## Professional Track

This track is tailored primarily for engineers currently practicing in the biomedical industry and students interested in pursuing a management career in the biomedical industry. A student shall complete 27 credit hours of course work and a 3 credit hour capstone project. The courses are organized into four core areas: Life Sciences, Mathematics, Engineering Management, and Biomedical Engineering. The student will choose two courses from the Engineering Management core based on personal training requirements. While the degree is structured as a non-thesis program, students will be required to conduct an industrial project (3 credit hours). The project will include contemporary topics and trends in biomedical engineering technology development and will require a formal report and presentation upon completion. Students receiving financial support from the department are not eligible for the Professional Track option.

Early in the program (before the end of the second term) the student and advisor will complete a study plan that specifies the courses that will comprise the program. A maximum of three credits of independent studies beyond the MS project may be included in a study plan.

Professional track students are required to take an oral final examination dealing with the objectives of their study plan. The student will briefly summarize the project report (20 minutes) as a part of the exam. The examining committee will include a minimum of three faculty members, at least two of whom have appointments in the Department.

## Course Requirements

### Approved Life Science Elective (3 credits) such as

| | | |
|---|---|---|
| BME 5410 | Biomedical Physiology and Engineering I | 3 |
| BME 5411 | Biomedical Physiology and Engineering II | 3 |
| PHZ 6255 | Molecular Biophysics | 3 |

### Mathematics Core (3 credits)

| | | |
|---|---|---|
| STA 5676 | Reliability Engineering | 3 |
| **or** | | |
| STA 5126 | Fundamentals of Design of Experiments | 3 |

### Approved Engineering Management Elective (6 credits) such as

| | | |
|---|---|---|
| EIN 5226 | Total Quality Management for Engineers | 3 |
| EIN 5322 | Engineering Management | 3 |
| EIN 5359 | Industrial Financial Decisions | 3 |
| MAN 6167 | Leadership in a Global Environment | 3 |

### Biomedical Engineering Core (18 credits)

| | | |
|---|---|---|
| Biomedical Engineering Electives | | 15 |
| BME 6907 | Master's Project | 3 |

## Research Track

The research track is geared to prepare the graduate for further graduate study or a career in biomedical research. A student shall complete a minimum of 30 credit hours. This includes a minimum of 24 hours of course work (15 credits of electives in specialty areas, 6 credits of mathematics core courses, 3 credits of life science elective), one semester of the Biomedical Engineering Seminar and 6 semester credit hours of Master's Thesis or 3 credit hours of Master's Project. Students electing Master's project will need to take one additional biomedical engineering elective course. Early in the program (before the end of the second term) the student and advisor will complete a study plan that specifies the courses that will comprise the program. A maximum of three credits of independent studies other than the MS thesis may be included in a study plan. Students receiving support from the department are not permitted to choose the project option.

All students in the research track are required to complete a research project under the supervision of an advisor and a committee. When the research is completed, the student should schedule a defense with an examining committee consisting of a minimum of three graduate faculty members (at least two of whom have appointments in the Department). The candidate should prepare to summarize the thesis or the report in the manner of a technical paper using appropriate visual aids in 40 minutes or less. Following the presentation, the candidate will answer questions related to the work from the audience and/or the committee. At the conclusion of the defense, the committee will agree upon the outcome - pass or fail - and report the results to the Graduate School. Following the exam the student will implement the committee's suggestions for improving the draft document. Each committee member must sign the approval form in the final document. Copies of the approved thesis must be provided to the advisor, Department, and the University Graduate School. Students should become familiar with the University Graduate School's regulations and deadlines available on line at **http://gradschool.fiu.edu**.

## Course Requirements

### Biomedical Engineering Core (21 credits)

All students in the Research Track must take three courses in one specialty area, and one course in each of the other two specialty areas. The current specialty areas are: 1) Basic research in engineered tissue model systems; 2) Diagnostic bioimaging and sensor systems; and 3) Therapeutic and reparative neurotechnology.

| | | |
|---|---|---|
| BME 6970 | Master's Thesis | 6 |
| **or** | | |
| BME 6907 | BME Master's Project | 3 |
| BME 6936 | Biomedical Engineering Seminar | 0 |

### Mathematics Core (6 credits)

| | | |
|---|---|---|
| STA 5126 | Fund Design of Experiments | 3 |
| **or** | | |
| STA 6176 | Biostatistics | 3 |
| BME 6705 | Nonlinear Systems Applications in Life Science | 3 |

### Approved Life Science Elective (3 credits) such as

| | | |
|---|---|---|
| BME 5410 | Biomedical Physiology and Engineering I | 3 |
| BME 5411 | Biomedical Physiology and Engineering II | 3 |
| PCB 6027 | Molecular and Cellular Biology II | 3 |
| PCB 6025 | Molecular and Cellular Biology I | 3 |
| PHZ 6255 | Molecular Biophysics | 3 |
| CHM 5325 | Physical Chemistry of Proteins | 3 |
| CHM 5506 | Physical Biochemistry | 3 |
| CHM 5503 | Physical Chem of Nucleic Acids | 3 |

## Combined BS/MS Degree Programs

This five-year program seamlessly combines a baccalaureate degree in biomedical, mechanical or electrical engineering with the Master's in biomedical engineering. To be considered for admission to the combined bachelor's/master's degree program, students must have completed 75-90 credits in the bachelor's degree program at FIU, have earned at least a 3.25 GPA on both overall and upper division courses, and meet the admissions criteria for the graduate degree program to which they are applying. Students need only apply once to the combined degree program, but the application must be submitted to Graduate Admissions before the student starts the last 30 credits of the bachelor's degree program. A student admitted to the combined degree program will be considered to have undergraduate status until the student applies for graduation from their bachelor's degree program. Upon conferral of the bachelor's degree, the student will be granted graduate status and be eligible for graduate assistantships. Students enrolled in the program may count up to 9 hours of graduate level courses (i.e., 5000 level or higher) as credits for both the undergraduate and graduate degree programs. For each of the courses counted as credits for both BS and MS degree, a minimum grade of 'B' is required. Upon completion of the combined BS/MS program, students must have accumulated a minimum of 24 hours of credits at the graduate (5000+) level. Students enrolled in the program are encouraged to seek employment with a department faculty member to work as student assistants on sponsored research projects.

## Doctor of Philosophy in Biomedical Engineering

The PhD program in Biomedical Engineering prepares graduates for industrial or academic research in one (or more) of three areas of specialization: 1) Basic research in engineered tissue model systems; 2) Diagnostic bioimaging and sensor systems; and 3) Therapeutic and reparative neurotechnology. Students can gain valuable exposure to clinical practice and research, and acquire real experience in the practice of engineering, product development, and commercialization. Semester-long clinical research experiences are provided, and students have the opportunity to participate in clinical/industrial R&D projects.

### Admission Requirements

A prospective student must meet all admission requirements stipulated in the University's Graduate Policies and Procedures. In addition, the requirements for admission to the doctoral program in Biomedical Engineering are stated as follows:
1. A student seeking admission to the doctoral program must have a Bachelor's or Master's degree in Biomedical Engineering, or other closely related field from an accredited institution.
2. A GPA of at least 3.0/4.0 in the upper division coursework of applicant's Bachelor's degree and a GPA of at least 3.3/4.0 in the applicant's Master's degree are required.

3. GRE scores with the following minimum scores on the individual components: verbal ≥150 and quantitative ≥ 153.
4. Three letters of recommendation.
5. A statement of research interests and goals.
6. International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of 80 on the iBT TOEFL or 6.5 overall on the IELTS is required.

The Graduate Admission Committee will examine credentials of all applicants. Applicants who have not satisfied the above will be evaluated for probationary or waiver admission.

### Degree Requirements

#### Credit Requirements

The PhD program requires a total of 90 credit hours beyond the BS degree. These credits are comprised of a minimum of 27 hours of coursework and a minimum of 24 hours of dissertation.

Applicants having a Master's Degree in Biomedical Engineering or closely related field from an accredited institution are given a maximum of 30 transferred semester hours. The graduate program committee and the academic adviser may recommend that applicants take additional courses based on their research needs and deficiencies. Applicants from science and engineering areas other than biomedical engineering will be expected to complete undergraduate courses selected to prepare them for graduate courses in their area of interest. Full admission into the graduate program requires the completion of these background courses with no grades below "C" and a grade point average of 3.0 or better.

### Course Requirements

The program of study will require completion of courses (beyond the BS degree) in the following categories:

#### *Biomedical Engineering* – minimum of 15 credits
Courses in this area must cover the major and minor specialty areas of the student. The three current specialty areas within biomedical engineering are:
1. Basic research in engineered tissue model systems
2. Diagnostic bioimaging and sensor systems
3. Therapeutic and reparative neurotechnology

#### *Engineering Mathematics* – minimum of 6 credits
Courses in this area must cover the broad areas of statistics and theoretical/numerical modeling. Example courses in each of these areas are:

**Statistics**
| | |
|---|---|
| STA 5126 | Fund Design of Experiments |
| | **or** |
| STA 6176 | Biostatistics |

**Theoretical modeling**
| | |
|---|---|
| BME 6715 | Mathematical Modeling of Physiological Systems |
| | **or** |
| BME 6716 | Mathematical Modeling of Cellular Systems |

**Numerical modeling**
BME 6705          Nonlinear Systems with Applications to Life Sciences

### *Life Science* – minimum of 6 credits
The life science courses maybe selected from approved electives such as:
BME 5410          Biomedical Physiology and Engineering I
BME 5411          Biomedical Physiology and Engineering II
BME 6019          Clinical Research Experience
PCB 6025          Molecular and Cellular Biology I
PCB 6027          Molecular and Cellular Biology II
PHZ 6255          Molecular Biophysics
CHM 5325          Physical Chemistry of Proteins
CHM 5506          Physical Biochemistry
CHM 5503          Physical Chem of Nucleic Acids

**Biomedical Engineering Seminar**
BME 7938          Doctoral BME Seminar                    0

**Qualifying Examination, Candidacy Requirements, and Final Defense**

Students must demonstrate Graduate knowledge acquisition in three incremental stages in order to be awarded a PhD in Biomedical Engineering:
- Qualifying Exam
- Proposal Defense (oral and/or written)
- Final Defense (oral)

Qualifying Exam is offered twice a year: one in January and once in August. Students entering the PhD with a Master's degree have to pass the Qualifying Exam within the first year in the PhD program. Students entering the PhD with a bachelor's degree, have to pass the Qualifying Exam within the first two years in the PhD program. In the semester prior to taking the Qualifying Exam, the student must declare an intention to take the exam and must declare a major area. In the event a student fails the Qualifying Exam, the student may retake it one more time the next time it is offered. A student who has successfully passed the Qualifying Exam and completed all the course work will be formally admitted to PhD candidacy.

The student will be required to prepare a formal dissertation proposal, and successfully defend the content of the proposal before his/her advisory committee. Immediately following the proposal defense, the student's dissertation committee will vote to pass the proposal, to have the student resubmit the proposal within six months, or to dismiss the student from the PhD program. A student can only resubmit his/her proposal once. The dissertation committee should be comprised of at least five members, at least three of whom should be biomedical engineering graduate faculty and at least one FIU graduate faculty member must be from outside biomedical engineering.

All students in the PhD program are required to complete a dissertation under the supervision of an advisor and committee. When the dissertation research is completed, the student should schedule a final defense with the examining committee. The dissertation, with an approval cover letter from the advisor, should be given to the examining committee for review not less than four weeks before the scheduled defense. The candidate should prepare to summarize the dissertation in the manner of a technical paper using appropriate visual aids in 40 minutes or less. Following the presentation, the candidate will answer questions related to the work from the audience and/or the committee. At the conclusion of the defense, the committee will agree upon the outcome pass or fail and report the results to the Graduate School. Following the exam the student will implement the committee's suggestions for improving the draft document. Each committee member must sign the approval form in the final document. Copies of the approved dissertation must be provided to the advisor, Department, and the University Graduate School. Students should become familiar with the University Graduate School's regulations and deadlines available on line at **http://gradschool.fiu.edu**.

## Course Descriptions
### Definition of Prefixes
BME-Biomedical Engineering; EEE-Engineering: Electrical and Electronics; EEL-Electrical Engineering; EGM-Engineering Mechanics

**BME 5005 Applied Biomedical Engineering Principles (3).** Biomedical engineering applications to instrumentation, transport phenomena, mechanics, materials and imaging. Prerequisite: Permission of the instructor.

**BME 5036 Biotransport Processes (3).** Transport of fluid, heat, and mass in the human body. Application to dialyzers and heart-lung devices. Prerequisites: BME 3632, BME 4100.

**BME 5105 Intermediate Biomaterials Science (3).** Materials used in prosthesis for skin and soft tissue, vascular implant devices, bone repair, and artificial joints. Structure-property relationships for biological tissue. Prerequisite: Permission of the instructor.

**BME 5316 Molecular Bioprocess Engineering (3).** Use of enzyme kinetics, bioreactor design, bioseparations and bioprocessing in the biomedical, biopharmaceutical, and biotechnology industries. Prerequisites: BCH 3033, BME 3632.

**BME 5340 Introduction to Cardiovascular Engineering (3).** Quantitative cardiovascular physiology, engineering applied to cardiovascular system: mechanics, materials, transport, and design.

**BME 5350 Radiological Engineering and Clinical Dosimetry (3).** Quantities for describing the interaction of radiation fields with biological systems. Absorption of radiant energy by biological systems. Applications to clinical dosimetry and radiation safety procedures. Prerequisite: Permission of the instructor.

**BME 5358L Clinical Rotation in Radiation Oncology (3).** Practical calibration of radiation therapy instruments, dose calculation and planning of radiation treatment under supervision of certified medical physicist. Prerequisite: BME 5505C.

**BME 5410 Biomedical Physiology and Engineering I (3).** Introductory course on cardiovascular and respiratory physiology and associated engineering concepts frequently encountered in the Biomedical Engineering field.

**BME 5411 Biomedical Physiology and Engineering II (3).** Introductory course on neural and musculoskeletal

physiology and associated engineering concepts frequently encountered in the Biomedical Engineering field.

**BME 5505C Engineering Foundation of Medical Imaging Instrument (3).** Engineering basis of medical imaging systems, including radiology, X-Ray CT, SPECT, PET, MRI, and laser and ultrasound based imaging, as well as instrument quality assurance procedures. Prerequisite: Permission of the instructor.

**BME 5560 Biomedical Engineering Optics (3).** Introduction to physical and geometrical optics of biomedical optical devices. Design of optical microscopes, endoscopes, fiber optic delivery systems, spectrometers, fluorometers, and cytometers. Prerequisites: Calculus, Differential Equations, Chemistry, and Physics.

**BME 5573 Nanomedicine (3).** Nano-scale tools and nanomaterials that result in new medical products and applications with special emphasis on imaging, diagnosis, drug delivery, regenerative medicine as well as new biomaterials. Prerequisites: BME 5105 or permission of the instructor.

**BME 5726 Protein Engineering (3).** Cloning, expressing and purifying proteins, and E. coli and Yeast expression systems. Design of proteins for specific end uses. Prerequisite: Permission of the instructor.

**BME 5731 Analysis of Physiological Control Systems (3).** Quantitative analysis methods and modeling of the self-regulation processes that result in homeostatic conditions in physiological systems with special emphasis on processes found in the human body. Prerequisites: Permission of the instructor, EEL 3003 or EEL 3110, BME 3404.

**BME 5803 Biomedical Device Design and Ethics (3).** User inputs; regulatory, ethical, societal, and environmental considerations; creativity; project management; prototype construction and testing; project feasibility; writing and oral communication. Prerequisite: Permission of the instructor.

**BME 5941 Biomedical Engineering Internship (1-3).** Engineering practice in biomedical applications at an industrial partner's site. Intern will be hired through cooperative agreement to conduct collaborative research with supervision of advisor.

**BME 6019 Clinical Research Experience (1).** Students are matched with and then "shadow" a clinician during procedures (diagnostic and interventional), and research and development activities. Prerequisite: Permission of the instructor.

**BME 6037 Controlled Delivery in Biomedicine (3).** Overview of methods of controlled drug delivery and their applications in biomedical engineering. Oral, pulmonary, transdermal, and polymeric delivery/devices. Prerequisites: BME 5105, BME 5036.

**BME 6212 Solid Mechanics Applications in Physiological Systems (3).** Solid mechanics and numerical methods as applied to analysis of the musculoskeletal system and trauma. Design application in orthotics and prosthesis and heart valves. Prerequisites: BME 4007 or permission of the instructor.

**BME 6235 Advanced Cardiac Mechanics (3).** Applications of principles of solid mechanics to the human cardiovascular system. 3-D reconstruction of the left ventricle, contractile properties and stress distribution in the myocardium. Prerequisite: BME 6212.

**BME 6265 Fluid Mechanics Applications in Physiological Systems (3).** Fluid mechanics principles including finite element and finite difference methods as it is applied to the analysis of various physiological systems will be covered. Process flow, diffusion and transport will be discussed in cardiovascular and pulmonary systems. Application of these primarily in the design of heart-lung machines, dialysis units, and heart valves will be discussed. Prerequisites: BME 4007 or permission of the instructor.

**BME 6266 Advanced Biofluid Mechanics (3).** Applications of fluid mechanics principles to human circulatory systems. Unsteady blood flow and wave propagation in elastic tubes. Influence of fluid dynamics on thrombosis and atherosclerosis. Prerequisite: BME 6265.

**BME 6315 Cytomic and Proteomic Measurement Techniques (3).** Principles and methods of cytomic, proteomic and genomic technology. Cellular probes, variance of protein expression. Description of the genome. Cytometry assays, protein structure, microarrays.

**BME 6330 Cell/Tissue Engineering: Theory and Methodology (3).** Overview of tissue engineering theory and practice with emphasis on cell behavior and morphology. Prerequisites: BME 5105, BME 3403/5702.

**BME 6345 Advanced Cardiovascular Engineering (3).** Engineering modeling, design, and measurements related to cardiovascular system, disease and diagnosis. Prerequisite: BME 5340.

**BME 6351C Radiation Safety in Biomedicine (3).** Theory and engineering basis of radiation safety in diagnostic and therapeutic radiology. Regulatory issues for the safe use of radiation in medicine. Prerequisite: BME 5350.

**BME 6353C Advanced Radiation Dosimetry (3).** State of the art of radiation treatment planning in radiation oncology. Intensity modulated radiation treatment methods and instruments.

**BME 6359L Clinical Rotation in Diagnostic Radiology (3).** Measuring of radiation fields for quality assurance of diagnostic radiology and nuclear medicine instruments under supervision of a certified medical physicist. Prerequisite: BME 5505C.

**BME 6501 Applied Biomedical and Diagnostic Measurements (3).** Fundamentals of biomedical measurements and the design of biomeasurement systems and devices. This includes transducers and electrodes, EMG, EEG, ECG and medical imaging techniques, and electrical safety. Prerequisites: BME 4007 or permission of the instructor.

**BME 6532 Molecular Imaging (3).** Production of PET and SPECT isotopes and radiopharmaceuticals, pharmacokinetics and experimental models of nuclear medicine tracer kinetics, imaging of molecular processes and function. Prerequisite: BME 6645.

**BME 6545 Biosensors and Nanobioelectronics (3).** Advanced topics in the design and practical application of bioelectronic devices such as biosensors, DNA nanowires, analytical electrochemistry and biomolecular electronics. Prerequisites: Permission of the instructor, CHM 1046, BCH 3033.

**BME 6563 Optical Spectroscopy (3).** Introduction to the scientific principles of optical spectroscopic technologies and their usage in the field of medicine. Prerequisite: Permission of the instructor.

**BME 6564 Optical Imaging Biomedicine (3).** Optical techniques for imaging the structure and function of biological tissues. Modeling of light transport in tissue (forward problem) and image reconstruction (inverse problem). The basic physics and engineering of each optical based imaging technique will be covered. Prerequisites: BME 4562 or BME 5560, MAP 2302.

**BME 6565 Quantitative Microscopy and Visualization (3).** Practical and useful projects in optical, confocal, near field, scanning probe and other advanced microscopy and cytometry. Spatial and spectral quantitation of physiologic measures in living tissue. Prerequisite: Permission of the instructor. Corequisite: BME 5560.

**BME 6645 Drug Transport Modeling (3).** Theoretical and experimental models of drug transport systems, computer simulations of fluid and mass transport in biomedical systems, pharmacokinetics modeling and molecular imaging. Prerequisite: BME 5036.

**BME 6705 Nonlinear Systems with Applications to Life Sciences (3).** Concepts and applications of nonlinear dynamics to life sciences. Specific nonlinear models arising from biology and medicine will be investigated using computer simulations. Prerequisite: Permission of the instructor.

**BME 6715 Mathematical Modeling of Physiological Systems (3).** Engineering modeling, design, and measurements related to cardiovascular system, disease and diagnosis. Prerequisite: Permission of the instructor.

**BME 6716 Mathematical Modeling of Cellular Systems (3).** Development of mathematical modeling techniques for engineers using cellular systems as an application. Biochemical reactions, membrane potentials, excitable cells, wave propagation, cellular regulation. Prerequisite: Permission of the instructor.

**BME 6750 Artificial Organs (3).** Theoretical and experimental models of artificial organs for drug delivery, extracorporeal devices, oxygenators, models of tissue engineered organs, computer simulations of fluid and mass transport. Prerequisites: BME 5036, BME 5105, BME 6645.

**BME 6763 Bioinformatics in Cytomics (3).** Biomedical data archiving, analysis and visualization. Medical imaging, microscopy imaging, multiparameter cytometry sensors, protein and gene sequencing data processing are emphasized.

**BME 6905 Independent Studies (1-3).** Individual research studies for qualified biomedical engineering graduate students. Work is to be performed under the supervision of an advisor.

**BME 6907 BME Master's Project (3).** Individual work culminating in a professional practice-oriented report suitable for the requirements of the Professional Track of the MS program in biomedical engineering. Prerequisite: Permission of the instructor.

**BME 6910 Supervised Research (1-6).** Graduate level biomedical engineering research carried out under the supervision of a faculty member.

**BME 6933 Workshop in Biomedical Engineering Techniques (1).** A short intensive treatment of specialized research topics or techniques in biomedical engineering. May be repeated for credit with different subject content. Prerequisite: Permission of the instructor.

**BME 6936 Biomedical Engineering Seminar (0).** Problems in Biomedical Engineering and results of ongoing research will be presented and discussed by invited experts. Prerequisite: Permission of the instructor.

**BME 6970 Master's Thesis (1-6).** Master's thesis on Biomedical Engineering is to be submitted and an oral presentation is to be made. Thesis should contain aspects of design to fulfill requirements for combined BS/MS program. Prerequisite: Advisor's permission.

**BME 7334C Cell/Tissue Engineering: Methods and Applications (4).** Overview of tissue engineering theory and practice with emphasis on cell behavior and morphology. Prerequisite: BME 6330.

**BME 7938 Doctoral Biomedical Engineering Seminar (0).** The course consists of oral presentations made by guests, faculty and graduate students on advanced topics and current research activities in Biomedical Engineering. Prerequisites: Permission of the major professor and Doctoral Candidacy.

**BME 7980 Ph.D. Dissertation (1-12).** Doctoral Research leading to the Ph.D. Biomedical engineering dissertation. Prerequisites: Permission of the major professor and Doctoral Candidacy.

**EEE 5261 Bioelectrical Models (3).** Engineering models for electrical behavior of nerve and muscle cells, electrode-tissue junctions, volume conductions in tissue and the nervous system as an electrical network. Prerequisites: EEE 4202C or permission of the instructor.

**EEE 5275 Bioradiation Engineering (3).** Spectrum of radiation sources, types of fields, properties of living tissue, mechanisms of field propagation in tissue. Applications in imaging and therapy, hazards and safety. Prerequisites: EEL 4410 or permission of the instructor.

**EEE 6285 Biosignal Processing I (3).** Characterizing biosignals by application of time and frequency domain analytic methods. Comparison of analog and digital processing. Engineering design for VLSI implementations in implantable devices. Prerequisites: EEE 4202C and EEL 6505 or permission of the instructor.

**EEE 6286 Biosignal Processing II (3).** Engineering design of advanced systems for processing biosignals. Methods for signal compression. Adaptive systems for automatic recognition. Application of artificial intelligence for signal classification. Prerequisites: EEE 6285 or permission of the instructor.

**EEL 5820 Digital Image Processing (3).** Image Fundamentals, Image Transforms, Image Enhancement,

Edge Detection, Image Segmentation, Texture Analysis, Image Restoration, and Image Compression. Prerequisites: EEL 3135 and knowledge of any programming language (FORTRAN, Pascal, C).

**EEL 6816 Electronic Neural Systems (3).** This course bridges electronics to the understanding of neurobiologically inspired models. Biological tasks and neural computations are studied in the context of networks and processing elements. Prerequisite: Permission of the instructor.

**EEL 6821 Computer Vision (3).** Image formation and image properties, radiance and irradiance, introduction to brain topography, color vision, visual machinery of the brain, statistical pattern classification and decision functions, the eigensystem and its computational aspects, stereo vision, motion vision, size and orientation independence. Prerequisite: EEL 5820.

**EEL 6836 Computer Visualization of Brain Electrical Activity (3).** Computer techniques for the visualization of brain electrical activity. Analysis of the origin of this activity as it relates to its measurement and visualization through computerized systems. Prerequisites: EEL 4510 or permission of the instructor.