

# BIOMEDICAL ENGINEERING DEPARTMENT

Robert R. McCormick School of  
Engineering and Applied Science  
Northwestern University

## Degree Requirements

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## BIOMEDICAL ENGINEERING PROGRAM - DEGREE REQUIREMENTS

Students in the biomedical engineering (BME) graduate program study approximately equal portions of engineering, life sciences, and mathematics. Biomedical engineering is by its nature very diverse and thus some breadth is required. Students, however, are expected to develop depth and understanding in one particular area of engineering and one of the life sciences. The areas of mathematical development are also somewhat flexible, with some breadth expected, but should be appropriate for the student's area of study. The portion of a student's effort in engineering, life sciences, and mathematics depends on his/her previous background.

Students generally enter the program in the fall and attend an orientation session the week before classes begin. At this session, faculty and their research interests will be introduced. Based on their areas of interest, students will be assigned *temporary* advisors who will help them choose courses for the first quarter. During the fall quarter, students in thesis-based programs should choose a *permanent* advisor who will supervise research work. Students are strongly encouraged, however, to consider possible areas of specialization before arriving on campus and to communicate directly with faculty members whose research interests match theirs. Information is sent to new graduate students before arrival on campus to aid in their choice of advisor. Research interests and phone numbers of faculty are given in the Biomedical Engineering Graduate Program Bulletin and on our home page - <<http://www.northwestern.edu/bme>>. All faculty members can also be reached by writing to the departmental office. Those students in thesis-based program should begin their research by the winter quarter.

Graduate students are admitted to The Graduate School, not the Engineering School. At Northwestern, almost all advanced degrees are conferred via The Graduate School. Thus, students must meet degree requirements as stipulated in *The Graduate School Bulletin*. In addition, biomedical engineering students are admitted to The Graduate School via the Biomedical Engineering Department; thus there are departmental requirements that the students must satisfy. The following pages generally outline the MS and PhD degree requirements as stipulated by both The Graduate School and the Biomedical Engineering Department.

## THE PhD PROGRAM

The purpose of Northwestern's doctoral degree program in biomedical engineering is to produce graduates who are qualified to fill research positions at the highest levels in private industry and in government laboratories, to teach in this field at universities, and to perform and direct original research on the staffs of universities, hospitals or companies. The students wishing to enter the PhD program must possess or obtain an MS degree or the equivalent. Students entering the program with an MS degree in a field other than biomedical engineering, e.g., traditional areas of biology, civil engineering, etc., are expected to concentrate their course work in their deficient areas.

Generally students seeking a PhD degree must do the following:

- complete sufficient and appropriate class work with a grade point average better than a 3.0 (B)
- complete an acceptable MS thesis
- pass a PhD qualification exam including the submission and defense of a PhD research proposal
- submit and successfully defend a PhD dissertation
- fulfill the teaching requirement.

The PhD qualification exam is comprised of a course-based component and a defense of a doctoral thesis proposal.

- (i) The course-based component of the exam ensures that the candidate has mastered the basics of the biomedical research area that the student has chosen to specialize in. These research areas or "tracks" are:

- Biomaterials
- Imaging
- Mechanics & Transport
- Neural Engineering
- Ocular Bioengineering
- Rehabilitation
- Tissue Engineering

- (ii) The thesis proposal is a document, written in the form of a grant proposal to a funding agency, that the student defends orally to a standing BME faculty committee. This exam includes general questions related to the area of research. The final document produced must be approved by the student's thesis advisor.

If the student fails either of these exams, they are normally allowed one opportunity to retake the exam, but this is at the discretion of the Graduate Program Committee.

Both The Graduate School and departmental requirements must be satisfied. All The Graduate School requirements for the PhD degree are explained in *The Graduate School Bulletin*; in brief these requirements that are in addition to our departmental requirements are:

1. Nine quarters of full time work (an MS, MA, MD etc. can count for up to three of these). Note that following the first three quarters of full-time study or its equivalent, three consecutive quarters of full-time registration or 5 consecutive quarters of 2/3 registration must be completed. Note that full-time registration for a quarter requires taking three units.
2. All courses taken for graduate credit must be listed in *The Graduate School Bulletin* (e.g. BME 395 does not qualify for graduate credit).
3. Admission to candidacy for the PhD degree follows completion of an acceptable Masters thesis and completion of the requirements for the course-based component of the qualification exam. This should be done before the end of 42 months after initial registration in The Graduate School . Extensions require approval of the Chair of the Graduate Program Committee.

In May of 2006, the Graduate Faculty voted to revise the PhD limitation of time policy in The Graduate School such that the Ph.D. degree requirements must be met within nine years of initial registration in a doctoral program. Beyond this time period, students will not be eligible to receive federal loans or to qualify for the university health insurance subsidy, nor will they be eligible for fellowships, traineeships, teaching or research assistantships, and scholarships. This status is considered less than half-time and therefore does not provide students with the ability to defer loans or extend visas. Petitions based on hardship will be reviewed on a case-by-case basis by the Dean of The Graduate School.

## Entering the PhD program with only a BS degree

The departmental requirements for the degree of Doctor of Philosophy for students who enter the PhD program with only a BS degree are as follows:

1. Completion of at least fourteen 300 or 400-level graduate courses for a letter grade (i.e. P/N courses are not accepted) and none of these courses can be a 499 (research credit). All of these courses must be science, engineering or mathematics courses. These courses must include a core curriculum of:
  - (i) At least two of the following courses: BME 401, 402, 403. Previous credit can be established for these courses by filing a petition approved by the Chair of the Graduate Program Committee, but if so, they must be replaced with other life science courses.
  - (ii) Two mathematics courses and a statistics course or two statistics course and a mathematics course from the following lists:

Mathematics: ES\_APPM 311-1, 2; ES\_APPM 411-1, 2, 3 ; ES\_APPM 420-1, 2, 3; ES\_APPM 421-1, 2, 3; ES\_APPM 442-1, 2, 3; ES\_APPM 446-1, 2, 3; ECE 328

Statistics: BMD\_ENG 420; STAT 330-1; STAT 330-2; STAT 351; IEMS 304
  - (iii) Of the remaining nine courses, at least five must be engineering classes, and all must be engineering, science or math courses, except by permission from Graduate Program chair.
  - (iv) Graduate-level classes should be selected in consultation with the student's advisor and must be reviewed and approved by the student's thesis committee. For each research "track", the BME department has a set of recommended required courses and restricted electives. The student's advisor and thesis committee can modify this set of recommendations as appropriate for each student. The courses chosen by the advisor and committee will have a direct impact on the course-based component of the qualifier (see item 5).
2. All first-year students are required to complete BMD\_ENG 512 in the fall, winter and spring quarters. Upon petition to the faculty, a student may delay completion of BMD\_ENG 512 until a subsequent time if the student is enrolled in a class that meets in conflict with BMD\_ENG 512.
3. By Thanksgiving, all first-year students are required to pick an advisor who agrees to take them as a research assistant for their Master's degree. Extensions of this time frame can be granted by the Chair of the Graduate Program Committee. The student may choose to remain with the same research advisor for their doctoral work, but this is not required. Students working as research assistants on the Evanston campus should begin their research during the Winter quarter of the first year. Students working as research assistants on the Chicago campus should begin their research during the Spring quarter of the first year.
4. Students are required to form a thesis committee by the beginning of the winter quarter of their first year. This committee must approve the student's proposed plan of study by the end of the winter quarter of the first year. This committee must meet, at least, once yearly, beginning in the second year, approve the progress of the student, and must meet at least twice before the final doctoral defense can be approved by this committee and scheduled. If this requirement is not met, there will be a 6 month delay for each missed committee meeting before the thesis proposal exam or final doctoral defense can be scheduled.

5. At the completion of the second year of the program, a review will be made of the academic progress of the student. If appropriate, the student will be asked to take an area examination to demonstrate mastery of the basics of the student's chosen area of study. This examination must be taken within 27 months of entering the program. Students can be exempted from this examination if they have received no grade below a B- in any required course or restrictive elective, and if they received no grade below an A- in the two courses required for their chosen area of study, as specified in their approved plan of study.
6. Students are required to complete a Master's degree with thesis within 42 months of matriculation except by petition approved by the Chair of the Graduate Committee. (Such a petition must include a letter from the student, co-signed by the advisor, indicating progress to date and a timeline to completion of the MS thesis.) The detailed requirements for a Master's degree with thesis are listed below, with the exception that the requirement for a comprehensive exam is satisfied by a regular yearly committee meeting in which the student thesis is approved. If this exam is successful, then completion of this Master's thesis requires only approval from the student's thesis advisor and does not require a separate thesis defense as is required for students whose terminal degree is a Master's degree. Upon completion of the course-based component of the qualification exam, an approved Master's thesis, and approval of the student's thesis committee, the student is admitted to PhD candidacy.
7. Within 6 months of completing their Master's degree (except by petition approved by the Chair of the Graduate Committee), the students must submit a written doctoral thesis proposal to a standing committee of the Biomedical Engineering Department (not the thesis committee). The format is to be similar to a proposal to a governmental funding agency. The student must then successfully defend this proposal orally to this same committee.
8. Students are required to complete and successfully defend a PhD thesis. This is in addition to the required thesis committee meetings.

## Entering the PhD program with a MS degree

The requirements for the degree of Doctor of Philosophy for students who enter the PhD program with a MS degree in engineering are as follows:

1. Completion of at least eight 300 or 400-level courses for a letter grade (i.e. P/N courses are not accepted) and none of these courses can be a 499 (research credit). All of these courses must be science, engineering or mathematics courses. These courses must include a core curriculum of:
  - (i) At least two of the following courses: BME 401, 402, 403. Previous credit can be established for these courses by filing a petition approved by the Chair of the Graduate Program Committee, but if so, they must be replaced with other life science courses.
  - (ii) One mathematics course and one statistics course:  
Mathematics: ES\_APPM 311-1, 2; ES\_APPM 411-1, 2, 3 ; ES\_APPM 420-1, 2, 3; ES\_APPM 421-1, 2, 3; ES\_APPM 442-1, 2, 3; ES\_APPM 446-1, 2, 3; ECE 328  
Statistics: BMD\_ENG 420; STAT 330-1; STAT 330-2; IEMS 304
  - (iii) Of the remaining four courses, at least two must be engineering classes, and all must be engineering, science or math courses, except by permission from Graduate Program chair.
  - (iv) Graduate-level classes should be selected in consultation with the student's advisor and must be reviewed and approved by the student's thesis committee. For each research "track", the BME department has a set of recommended required courses and restricted electives. The student's advisor and thesis committee can modify this set of recommendations as appropriate for each student. The courses chosen by the advisor and committee will have a direct impact on the course-based component of the qualifier (see item 5).
2. All first-year students are required to complete BMD\_ENG 512 in the fall, winter and spring quarters. Upon petition to the faculty, a student may delay completion of BMD\_ENG 512 until a subsequent time if the student is enrolled in a class that meets in conflict with BMD\_ENG 512.
3. By Thanksgiving, all first-year students are required to pick an advisor who agrees to take them as a research assistant. Students working as research assistants on the Evanston campus should begin their research during the Winter quarter. Students working as research assistants on the Chicago campus should begin their research during the Spring quarter.
4. Students are required to form a thesis committee before the winter quarter of their first year. This committee must approve the student's proposed plan of study by the beginning of the winter quarter of the first year. This committee must meet, at least, once yearly, beginning in the second year, approve the progress of the student, and must meet at least twice before the final defense can be approved by this committee and scheduled. If this requirement is not met, there will be a 6 month delay for each missed committee meeting before the thesis proposal exam or final doctoral defense can be scheduled.
5. At the completion of the second year of the program, a review will be made of the academic progress of the student. If appropriate, the student will be asked to take an area examination to demonstrate mastery of the basics of the student's chosen area of study. This examination must be taken within 27 months of entering the program. Students can be exempted from this examination if they have received no grade below a B- in any required course or restrictive elective, and if they received no grade below an A- in the two courses required for their chosen area of study, as specified in their approved plan of study. Upon completion of the course-based component of the qualification exam and approval of the student's thesis committee, the student is admitted to PhD candidacy.

6. Within 30 months of matriculation, the students must submit a written doctoral thesis proposal to a standing committee of the Biomedical Engineering Department (not the thesis committee). The format is to be similar to a proposal to a government funding agency. The student must then orally defend this proposal to this same committee.
7. Students are required to complete and successfully defend a PhD thesis. This is in addition to the required thesis committee meetings.

## Entering the PhD program from alternate paths

The requirements for the degree of Doctor of Philosophy for students **who enter the PhD program with a MS degree, without an engineering degree and with a strong biology or medicine background** (as determined the the Chair of the Graduate Program Committee) **and for students in the MSTP program**, are as follows:

1. Completion of at least eight 300 or 400-level courses for a letter grade (i.e. P/N courses are not accepted) and none of these courses can be a 499 (research credit). All of these courses must be science, engineering or mathematics courses. These courses must include a core curriculum of:
  - (i) At least one of the following courses: BME 401, 402, 403. If previous credit can be established for at least two of these course (and for students in the MSTP program), this requirement may be replaced by one life science course. Previous credit must be approved by the Chair of the Graduate Program Committee.
  - (ii) Two mathematics courses and a statistics course:

Mathematics: Math 221; ES\_APPM 311-1, 2; ES\_APPM 411-1, 2, 3 ; ES\_APPM 420-1, 2, 3; ES\_APPM 421-1, 2, 3; ES\_APPM 442-1, 2, 3; ES\_APPM 446-1, 2, 3; ECE 328

Statistics: BMD\_ENG 420; STAT 330-1; STAT 330-2; IEMS 304

For those with a weak Mathematics background, Math 221 may be additionally required as determined by the Graduate Program Chair.
  - (iii) Of the remaining four 300 or 400 level courses, at least three must be engineering classes, and all must be engineering, science or math courses, except by permission from Graduate Program chair.
  - (iv) Graduate-level classes should be selected in consultation with the student's advisor and must be reviewed and approved by the student's thesis committee. For each research "track", the BME department has a set of recommended required courses and restricted electives. The student's advisor and thesis committee can modify this set of recommendations as appropriate for each student. The courses chosen by the advisor and committee will have a direct impact on the course-based component of the qualifier.
2. Items 2-7 are the same as for students entering PhD program with MS degree and an engineering degree.

## **Requirements for Thesis Committee**

A thesis committee for a PhD thesis must consist of at least four faculty members with a minimum of two regular members, including the chair, from the Biomedical Engineering Department, a minimum of two, including the chair, from The Graduate School faculty, and a minimum of three who are full-time members of the Northwestern faculty.

## **Course-based Component of Qualification Exam**

Before the end of the winter quarter of the first year (beginning of the winter quarter for students entering with a Master's degree), the student, with agreement from his or her advisor and thesis committee, must choose a "track". Associated with this track will be a set of required courses, and a list of restricted electives, as recommended by the BME department. This list can be modified by the student's thesis committee. At the completion of the Spring quarter of the second year (first year for students entering with a Master's degree), the BME department will determine whether a course-based qualifier is necessary for the student, based on grades in these courses and recommendations from the thesis committee.

For those students taking a course-based exam, the thesis committee will designate a course instructor in an area in which the student has shown weakness to prepare an exam typical of a final exam in that area. The instructor, in consultation with the thesis committee, will decide whether the performance of the student on the exam is adequate. A student may retake this exam once with permission of the chair of the BME Graduate Program Committee, but only after a six month period has elapsed.

## **Thesis Proposal Component of Qualification Exam**

Every six months, a standing committee of the BME department (selected by the department chairman) will be formed to review thesis proposals of PhD candidates. The deadline for submittal of the proposal will be posted by the BME department at least two months previous to the deadline. The written proposal is limited to 15 pages of text (excluding references) and no more than 7 pages of the text can be devoted to preliminary studies.

The focus of this proposal should be on proposed studies, as opposed to work already completed. Two weeks after submittal of this proposal, the student will orally defend this proposal to this same committee. In the event of an unsuccessful defense, this proposal defense can be repeated, at most, once.

Upon successful completion of the examination, the thesis proposal must be presented to the student's thesis advisor for evaluation. The student must make such changes to the document as are required by the advisor for it to become the Research Thesis Proposal.

The thesis proposal defense should occur within 6 months of completion of the Master's degree for students entering without a Master's degree, or within 30 months for students entering with a Master's degree.

## **Thesis/Dissertation Requirements**

Upon written recommendation from the thesis committee and following a thesis committee meeting, a final thesis defense can be scheduled. Notification of this defense must be circulated to all faculty members of the department a minimum of three weeks before the defense and cannot be circulated prior to written approval by the thesis committee. All thesis committee members must receive a copy of the thesis at least two weeks prior to the defense. The thesis defense is open to all members of the Northwestern community and their guests.

An acceptable dissertation resulting from original research must conform to requirements set forth in Appendix A. Each student must submit three unbound copies of the PhD dissertation thesis to the department office. These will be bound by the department and given to the student, the advisor and the departmental library. Additionally, two unbound copies must be submitted to The Graduate School, one of which will be given to the University Library.

## **Teaching Requirement for PhD students**

Whether working in academia, industry, or a research laboratory, recipients of a PhD degree are confronted with the need to educate those around them. Didactic lectures in academia are the most common form of teaching. But presentations at international meetings and in corporate boardrooms are also forums requiring teaching skills. Even patents must teach the reader the utility and novelty of the disclosed design or process. Thus, the Biomedical Engineering Department requires that all PhD students serve as teaching assistants at some time during their tenure at Northwestern. The teaching requirement can be fulfilled in two ways: a student can serve two quarters as an unpaid, part-time TA (approximate time commitment: 6 hr/week) or for one quarter as a paid, full-time TA (approximate time commitment: 20 hr/week). The duties of a TA include but are not limited to tutoring students, conducting problem solving sessions, preparing and supervising laboratory session, and grading. It is expected that some students will want more than this minimal teaching experience; where possible these students will be accommodated.

## THE MS-only PROGRAM

The purpose of the MS-only program is to produce graduates who will fill positions in research and development in the field of biomedical engineering or pursue further formal education. Graduates may expect to seek employment on the research staffs of engineering schools, medical schools, hospitals, industrial firms, and government laboratories.

We have three different Master's programs all of which lead to an MS (switching between these programs, once started, requires approval of the graduate program chair):

- (i) Master's degree without thesis
- (ii) Master's degree with thesis
- (iii) A combined BS/MS program with or without Master's thesis

Completion of the Master's degree program may take as little as three quarters, if done without a thesis. With a thesis, a typical time for completion would be 2.5 to 3.5 years.

Graduate programs are administered by The Graduate School, so there are both The Graduate School and Biomedical Engineering Department requirements to satisfy for the degree. The detailed requirements of The Graduate School are listed in *The Graduate School Bulletin*, and include but may not be limited to:

- (i) Three quarters of residence at Northwestern.
- (ii) A grade average for all work presented for the degree of at least B (3.0).
- (iii) All courses taken for graduate credit must be listed in *The Graduate School Bulletin* (e.g. BME 395 does not qualify for graduate credit).

## MS degree without thesis

The requirements for the degree of Master of Science (without thesis) are as follows:

1. Completion of at least twelve 300-level or higher courses (but no more than two units of 499 or 590; only 1 unit of 499 or 590 may be taken for credit in one term). These courses must include a core curriculum of:
  - (i) At least two of the following courses: BME 401, 402, 403. Previous credit can be established for these courses by filing a petition approved by the Chair of the Graduate Program Committee, but if so, they must be replaced with other life science courses.
  - (ii) One mathematics course and one statistics course from the following lists:

Mathematics: ES\_APPM 311-1, 2; ES\_APPM 411-1, 2, 3 ; ES\_APPM 420-1, 2, 3; ES\_APPM 421-1, 2, 3; ES\_APPM 442-1, 2, 3; ES\_APPM 446-1, 2, 3; ECE 328

Statistics: BMD\_ENG 420; STAT 330-1; STAT 330-2; IEMS 304.
  - (iii) Of the remaining courses at least five must be engineering classes, and all must be engineering, science or math courses, except by permission from Graduate Program chair.
  - (iv) The above requirements may be satisfied, upon petition to the faculty, by substitution of other appropriate classes at Northwestern that provide competency similar to that provided by the required classes.
2. All students are required to complete BMD\_ENG 512 in the fall, winter and spring quarters. Upon petition to the Graduate Committee, a student may be exempt from one quarter of BMD\_ENG 512 if the student is enrolled in a class that meets in conflict with BMD\_ENG 512. Exemption from attending BME 512 will require the student to complete additional work related to the topics covered during the class.
3. A student can satisfy The Graduate School requirement for a comprehensive final exam in one of two ways: 1) completion of a project (a minimum of one BMD\_ENG 499) that includes a written report (length 25 pages or more) approved by a faculty member in the BME department, or 2) completion of three classes with significant project components from a list provided in September of each year.

## MS degree with thesis

The requirements for the degree of Master of Science (with thesis) are as follows:

1. Completion of at least eight 300 or 400-level graduate courses for a letter grade (i.e. P/N courses are not accepted) and none of these courses can be a 499 (research credit). All of these courses must be science, engineering or mathematics courses. These courses must include a core curriculum of:
  - (i) at least two of the following courses: BME 401, 402, 403. Previous credit can be established for these courses, but if so, they must be replaced with another life science course.
  - (ii) One mathematics course and one statistics course:

Mathematics: ES\_APPM 311-1, 2; ES\_APPM 411-1, 2, 3 ; ES\_APPM 420-1, 2, 3; ES\_APPM 421-1, 2, 3; ES\_APPM 442-1, 2, 3; ES\_APPM 446-1, 2, 3; ECE 328

Statistics: BMD\_ENG 420; STAT 330-1; STAT 330-2; STAT 351; IEMS 304.

For those students that do not have an adequate mathematics background, Math 221 may also be additionally required at the discretion of the Chair of the Graduate Program Committee; B or above is required in the course.
  - (iii) Of the remaining four courses, at least two must be engineering courses, and all must be engineering, science or math courses, except by permission from Graduate Program chair.
  - (iv) The above requirements may be satisfied, upon petition to the faculty, by substitution of other appropriate classes at Northwestern that provide competency similar to that provided by the required classes.
2. All students are required to complete BMD\_ENG 512 in the fall, winter and spring quarters. Upon petition to the Graduate Committee, a student may be exempt from one quarter of BMD\_ENG 512 if the student is enrolled in a class that meets in conflict with BMD\_ENG 512. Exemption from attending BME 512 will require the student to complete additional work related to the topics covered during the class.
3. Students are required to complete and defend a Master's thesis to satisfy the requirement for a comprehensive exam. An examination committee for an MS thesis consists of at least three faculty members with one, including the chair, from the department, a minimum of two, including the chair, from The Graduate School faculty, and a minimum of two who are full-time members of the Northwestern faculty. All committees must be approved by the department two weeks prior to a defense. If a student selects a research advisor who does not have an appointment in the Biomedical Engineering Department, it is incumbent upon the student to select a faculty member within the department who will chair the examination committee. Further, the student should meet and confer regularly with the committee chair regarding coursework and research progress.
4. Students who wish to transfer into the PhD program from the MS-only program with thesis can only do so only upon completion of their MS degree. All courses taken will be counted toward the PhD degree, and they will be subject to the same qualification exam requirements as those entering the PhD program. Approval for this transfer requires approval of thesis committee and graduate admission officer (provided doctoral thesis advisor has been identified and has approved).
5. An acceptable dissertation resulting from original research must conform to requirements set forth in Appendix A. Each student must submit three unbound copies of the MS thesis to the department office. These will be bound by the department and given to the student, the advisor and the departmental library.

## THE COMBINED BS/MS PROGRAM

Two programs offer combined BS/MS degrees. Details of the requirements for the undergraduate degree and the determination of which courses count for undergraduate study and which courses for graduate study are determined by the McCormick Undergraduate Engineering Office, BME and the Graduate School.

The first program is a McCormick-wide program that is a course-based degree. This can be completed in four or five years, although we advise against trying to complete this program in four years. The graduate requirements are the same as for the MS degree without thesis described above.

The second program is a combined degree of Bachelor's of Science and Master of Science with thesis. It is a special program for outstanding undergraduates who have established research relationships with BME faculty members. Admission is considered only during the fall of the student's senior year, with a November 1<sup>st</sup> deadline. Typically, a student entering this program in the winter of their senior year will complete the program at the end of the spring or summer quarter of the next year. Earlier completions will not be considered. If the student takes three courses during the fifth year of the program, completion of the program will be no earlier than the end of the summer of the fifth year.

### Admission requirements (no exceptions):

- 3.5 grade point average or higher in undergraduate studies
- will have completed sufficient courses before the end of fourth year such that only 3 (or less) courses are left to complete during the fifth year of the program
- have conducted at least two quarters of undergraduate research (399 or paid research) with chosen advisor
- approval by the Department Chairman or a committee appointed by the Department Chairman

## BS/MS degree with thesis

The graduate requirements for a combined degree of Bachelor's of Science and Master of Science (with thesis) are as follows:

1. Completion of at least six 300 or 400-level graduate courses for a letter grade (i.e. P/N courses are not accepted) and none of these courses can be a 499 (research credit). As indicated above, no more than 3 courses can be taken during the last year of study, and preferably only one or two courses will be taken (this is to allow a focus on completion of research during the final year). All of these courses must be science, engineering or mathematics courses. These courses must include a core curriculum of:
  - (i) One mathematics course and one statistics course:  
Mathematics: ES\_APPM 311-1, 2; ES\_APPM 411-1, 2, 3; ES\_APPM 420-1, 2, 3; ES\_APPM 421-1, 2, 3; ES\_APPM 442-1, 2, 3; ES\_APPM 446-1, 2, 3; ECE 328  
Statistics: BMD\_ENG 420; STAT 330-1; STAT 330-2; STAT 351; IEMS 304.
  - (ii) Of the remaining four courses, at least one must be an engineering course and one must be a life science course; all must be engineering, science or math courses, except by permission from Graduate Program chair.
  - (iii) Note that at least 3 more units of 590 registration is necessary to meet the Graduate School requirement of 3 quarters of registration.
2. If the student has taken 301, 302 and 303 as an undergraduate, there is not a physiology requirement as there is for the other graduate BME degrees. If only two of these courses were taken as an undergraduate, then the graduate equivalent of the remaining physiology course in this sequence must be completed.
3. All students are required to complete 3 quarters of BMD\_ENG 512. Upon petition to the Graduate Committee, a student may be exempt from one quarter of BMD\_ENG 512 if the student is enrolled in a class that meets in conflict with BMD\_ENG 512. Exemption from attending BME 512 will require the student to complete additional work related to the topics covered during the class.
4. Students are required to complete and defend a Master's thesis to satisfy the requirement for a comprehensive exam. An examination committee for an MS thesis consists of at least three faculty members with one, including the chair, from the department, a minimum of two, including the chair, from The Graduate School faculty, and a minimum of two who are full-time members of the Northwestern faculty. All committees must be approved by the department two weeks prior to a defense. Further, the student should meet and confer regularly with the committee chair regarding coursework and research progress.
5. An acceptable dissertation resulting from original research must conform to requirements set forth in Appendix A. Each student must submit three unbound copies of the MS thesis to the department office. These will be bound by the department and given to the student, the advisor and the departmental library.

## GRADES

Credit for the MS or PhD degree will be given only for courses in which a grade of A, B, or C has been received. No P/N registration will be accepted. A grade point average greater than a 3.0 is required for graduation for a PhD (note that this is higher than The Graduate School requirement); a grade point average greater than or equal to a 3.0 is required for graduation for a Master degree. 499s do not count toward the grade point average as determined by the BME department, except with approval by the Chair of the Graduate Program Committee. A student whose overall grade average is not above a 3.0 is not meeting academic standards and will be placed on probation. Failure to remedy that situation may lead to dismissal by The Graduate School or the Biomedical Engineering Department.

An incomplete grade (Y or K) for any course except Post-Candidacy Research (590) must be removed within one year of the official ending of the course. At the research director's option, 590 may be graded as incomplete (K) until the research is finished. The time limit for removal of incomplete research grades is 5 years.

## REGISTRATION

All students using departmental facilities in any quarter must be registered. A full-time registration of 4 units of courses and research (BMD\_ENG 590) is typical. For a quarter in which no courses are taken and full time is devoted to research, registration with reduced tuition, TGS 588 (Resident Master's Study) or TGS 598 (Resident Doctoral Study) can be elected. Typically, most students register for four units of courses and/or research (BMD\_ENG 590) until their residency requirement has been satisfied, but only three units are necessary to get credit for one quarter of residency. Registration for the *summer quarter* at a reduced tuition is possible. Students are reminded that registration is **required** for any graduate student receiving a paycheck from the University in connection with her or her course of study.

Four types of registration with reduced tuition are available:

### **TGS 588 Resident Masters Study**

This registration is available for MS-only students who have completed at least 3 quarters of full-time, full-tuition registration toward the MS degree and need to maintain full-time registration status.

### **TGS 598 Resident Doctoral Study**

This registration is available for students who have completed at least 3 quarters of full-time, full-tuition registration toward the doctorate but have not yet been admitted to candidacy. It is normally used by biomedical engineering Ph.D. students in the *summer* quarters.

### **TGS 599 Post-Candidacy Research**

Following admission to candidacy and completion of residence and course requirements, students who have not yet finished their PhD research must register for TGS 599 for at least 3 quarters. *Students in the PhD program should plan to complete the requirements for admission to candidacy so as to be able to register for TGS 599, Post-Candidacy Research, at the earliest reasonable date.*

### **TGS 503 Resident Research Continuation**

This registration should be used after completion of the required TGS 599 registration for every additional quarter until the completion of the PhD program or the end of the ninth year of study.

### **TGS 513 Post-Ninth Year Research**

This is required for any student that has not completed their doctorate by the end of the ninth year of study.

## **PhD PROGRAM (or MS with thesis) - Recommended Pattern of Registration**

### **First Year**

- September New student orientation, plan program for fall quarter (typically 4 courses). Regular full-time registration - 4 units, all courses (i.e., no research units). Begin contacting possible research advisors.
- November Deadline for selecting research area and advisor.
- December Plan program for winter quarter with advisor (2-4 courses) and choose thesis committee. Those doing research on Evanston campus start their research. Register with sufficient units of 590 to bring total to, at least, 3 units.
- March Plan program for spring quarter with advisor (0-2 courses) with sufficient units of 590 to bring total to, at least, 3 units. Those doing research on Chicago campus start their research
- May Preregister for summer quarter 588 (Resident Master's Study) or 598 (Resident Doctoral Study).
- May Preregister for fall quarter.

### **Second Year**

- September Plan second year program with advisor. Regular full-time registration for fall quarter, including sufficient units of 590 to bring total registration to, at least, 3 units.
- December Registration for winter quarter with sufficient 590s to bring total to, at least, 3 units. Schedule first research committee meeting.
- March Registration for spring quarter, with sufficient 590s to bring total to, at least, 3 units. File candidacy form for MS degree.
- May or August Complete PhD candidacy forms (if appropriate).
- May Preregister for 598 for summer.
- May Preregister for fall quarter (see below).

### **Third and Subsequent Years**

Regular full-time registration during fall, winter, and spring quarters, using 590, 599 or 503 to bring total to, at least, 3 units each quarter.

## **MS-only PROGRAM - Recommended Pattern of Registration**

- September New student orientation, plan program for fall quarter (typically 4 courses). Regular full-time registration - 4 units, all courses.
- Sept.-Nov. Begin contacting possible research advisors if interested in MS with thesis option.
- December Plan program for winter quarter with advisor (either 4 courses or 3 courses and 1 unit of research).
- March Plan program for spring quarter with advisor (either 4 courses or 3 courses and 1 unit of research).
- March File for MS candidacy if MS without thesis.
- May Pre-register if necessary for summer quarter 588 (Resident Master's Study).

## **FINANCIAL AID**

All PhD program applications are automatically considered for all scholarships and fellowships; no separate application is required. (No financial aid is currently available for students in the MS-only program.) Fellowships generally provide monthly stipends and pay tuition. Award decisions for first-year students are made between late February and early April for the next academic year. Fellowship recipients are expected to devote full time to their study and research in biomedical engineering.

Research assistantships involve participation in ongoing research projects, usually in the area of the student's dissertation interest. Incoming doctoral students will be informed as to which faculty members have projects available. If the student and the faculty member find that they have a good fit, then the faculty member provides research assistantship funding the student.

Students normally spend at least one academic quarter (usually 3 quarters) on campus before becoming eligible for these assistantships. During this time they become acquainted with ongoing research and choose an advising professor, thus allowing the professor time to evaluate the student's potential contribution to the project.

Teaching assistantships are also available. These are generally given on a quarter-by-quarter basis to graduate students who have been at Northwestern at least one year. Information regarding teaching assistantships is sent to all graduate students during the spring quarter.

All full-time graduate students in good academic standing are eligible to apply for student loans. These loans are provided by the combined efforts of the federal government, Northwestern, and cooperating financial institutions, and should be regarded as supplemental financial resources rather than the primary means of financing advanced degrees.

## **NORTHWESTERN UNIVERSITY NONDISCRIMINATION POLICY**

It is the policy of Northwestern University not to discriminate against any individual on the basis of race, color, religion, national origin, sex, sexual orientation, marital status, age, disability or veteran status in matters of admissions, employment, housing or services, or in the educational programs or activities it operates, in accordance with civil rights legislation and University commitment.

Any alleged violations of this policy or questions regarding the law with respect to nondiscrimination should be directed to Director of Equal Opportunity, Affirmative Action, and Disability Services, 720 University Place, Evanston, Illinois 60208-1147, phone (847) 491-7458; Office of the Provost, Rebecca Crown Center, Evanston, Illinois 60208-1101, phone (847) 491-5117.

Northwestern University reserves the right to change without notice any statement in this booklet concerning, but not limited to, rules, policies, tuition, fees, curricula, and courses.

## **DISABILITIES**

Director of Services for Students with Disabilities, Scott Hall 39 and 40, 467-5530, 467-5533 (TTY)

It is Northwestern University policy to ensure that no qualified student with a disability is denied the benefits of, excluded from participation in, or otherwise subjected to discrimination in any University program or activity. In response to a request made by a qualified student with a disability, the University will arrange, at no cost to the student, for the provision of educational auxiliary aids, including sign-language interpreters, real-time captioners, note takers, readers, and tutors, determined by the University to be necessary to afford such student the opportunity for full participation in University programs.

It is important for Northwestern University students who need assistance with regard to any disability to notify

Services for Students with Disabilities (SSD) so the University can assist them in obtaining appropriate services. Students may call 847-467-5530 or TTY 847-467-5533 for further information. The SSD office, at 601 University Place, Evanston, serves both the Evanston and Chicago campuses.

*Services for Students with Disabilities*, a brochure describing various support services for students with disabilities, is available in University admissions offices and from the Services for Students with Disabilities office. There is also a brochure that includes maps of the Evanston and Chicago campuses indicating building access and parking locations. For more information, contact SSD:

e-mail: [SSD@northwestern.edu](mailto:SSD@northwestern.edu), phone: 847-467-5530, TTY: 847-467-5533 , Web Page: [www.stuaff.northwestern.edu/disability](http://www.stuaff.northwestern.edu/disability)

## APPENDIX A: GUIDELINES FOR PREPARING THE DISSERTATION

All students should obtain a copy of the brochure "Preparation and Submission of the Dissertation" from the Graduate School. The standards given there must be followed for the PhD thesis and the department recommends that these be followed for the MS thesis as well. References in dissertations must conform to the reference style used by the journal *Vision Research*. Their guidelines are reproduced below, with slight modifications.

1. References should be cited in the text by giving the last name of the author (or authors) followed by the year of publication in parentheses, e.g. Hays (1963), Van den Brink and Bouman (1957). If there are three or four authors, citations should read Kuhn, Bennett, Michel-Villaz and Chabre (1981), first citation; Kuhn et al. (1981), second citation. If there are five or more authors, even the first citation should read Schmidt et al. (1991). If there is more than one work by an author (or authors) in a given year, then they should be labelled alphabetically within each year (e.g. Rushton, 1965a, b).
2. The full references should be typed on separate pages and placed at the end of the thesis. They should not be given as footnotes. References should include the names of all the authors and their initials, the year of publication in parentheses, the full title of the article or book, name of the journal, the volume number and the pages. For books, the city of publication and the publisher should be given. The following may serve as illustration:

Zrenner, E & Gouras, P (1981). Characteristics of the blue sensitive cone mechanism in primate retinal ganglion cells. *Vision Research*, **2**, 1605-1609.

Semmlow, J L & Hung, G K (1983). The near responses: Theories of control. In C M Schor & K J Ciuffreda (Eds.), *Vergence eye movements: Basic and clinical aspects* (pp. 175-195). London: Butterworths.

Unpublished work, work in press, or conference proceedings should be cited only exceptionally.