

**WORCESTER POLYTECHNIC INSTITUTE**

**Department of Biomedical Engineering**

Master of Engineering in Biomedical Engineering

Master of Science in Biomedical Engineering

Master of Engineering in Clinical Engineering

Ph.D. in Biomedical Engineering

**WPI/UNIVERSITY OF MASSACHUSETTS  
MEDICAL SCHOOL (UMMS)**

Joint PhD Program in Biomedical Engineering  
and Medical Physics

**Graduate Student Handbook  
Version Fall 2005**

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## **1. Introduction**

### **1.1. Overview and Scope of Handbook**

The purpose of this Handbook is to provide students, faculty, and staff with an up-to-date source of information on the different Biomedical Engineering (BME) graduate programs at Worcester Polytechnic Institute (WPI), including the Joint PhD Program administered both by WPI and the Graduate School of Biomedical Sciences (GSBS) at the University of Massachusetts Medical School (UMMS).

It is divided into the following chapters:

- Chapter 1: General descriptions for the different degree and certificate programs offered in BME. This chapter is primarily intended for prospective students seeking guidance and insights prior to a full application.
- Chapters 2-6: Detailed information about each degree program. These chapters are primarily intended for both prospective students seeking more information about a particular degree program, including admission requirements and application procedures, and current graduate students seeking information about degree requirements and procedural issues specific to a particular degree program. Each chapter covers a single degree program in detail.

Prospective and current students should also read WPI's Graduate Catalog and, for students in the Joint PhD Program, the Faculty/Student Handbook for the GSBS at UMMS.

### **1.2. Programs of Study in Biomedical Engineering (BME)**

The goal of the BME graduate program is to apply engineering principles and technologies as solutions to significant biological and medical problems. Students trained in these programs have found rewarding careers in major medical and biomedical research centers, academia, medical care industries, and entrepreneurial enterprises.

#### **1.2.1. Doctor of Philosophy (PhD) Degree Programs**

There are two PhD options in BME: The PhD in Biomedical Engineering at WPI and the PhD in Biomedical Engineering and Medical Physics offered jointly by WPI and UMMS. In both programs, the degree of Doctor of Philosophy (PhD) is conferred on candidates in recognition of high attainments and the ability to conduct original independent research. Graduates of either program will be prepared to affiliate with academic institutions and the growing medical device and biotechnology industry, which have become major economic factors in the Commonwealth of Massachusetts and the United States.

The Joint WPI/UMMS PhD Program employs the advanced technical knowledge and expertise of engineering and medical faculty to provide students with the knowledge and skills necessary to apply engineering and scientific principles to medically-related problems. A unique aspect of this program is that it utilizes the expertise and resources available from a public university and a private institution of higher education in a synergistic manner to train students in the application of engineering to medical research. The PhD degree in this program is awarded jointly by WPI and UMMS, with appropriate designation on the diploma.

The table below briefly outlines the major differences between the two PhD Programs in BME.

<b>WPI PhD Program in Biomedical Engineering</b>	<b>WPI/UMMS Joint PhD Program in Biomedical Engineering and Medical Physics</b>
Applicants are expected to have an undergraduate degree and a strong background in engineering and mathematics. Programs are available at WPI to make up for a lack of course work in these areas.	Applicants are expected to have an undergraduate degree and a strong background in engineering AND to have had one semester of organic chemistry, a full year of biology, and mathematics through differential equations.
Program places a greater emphasis on the engineering principles and their application to biomedical engineering and industry.	Program places a greater emphasis on the life sciences and its application to medical and biomedical research.
Acceptance into the program and financial aid are not coupled. A consideration of financial aid is separate from acceptance into the program.	Acceptance and financial aid are coupled. Students accepted into the program will receive institutional stipend and tuition support for the first two calendar years in the program. Support in subsequent years is derived from the student's Research Advisor.
Students must satisfy WPI degree requirements for the doctorate.	Students must simultaneously satisfy both WPI and UMMS degree requirements for the doctorate.
The PhD degree is awarded by WPI.	The PhD degree is awarded jointly by WPI and UMMS, with appropriate designation on the diploma.

### 1.2.2. Master's Degree Programs

There are three master's options in BME: the Master of Science (MS) in Biomedical Engineering, the Master of Engineering (ME) in Biomedical Engineering, and the Master of Engineering (ME) in Clinical Engineering. While the expected levels of student academic performance are the same for all options, they are oriented toward different career goals. The Master of Science option in BME is oriented toward the student who wants to focus on a particular facet of biomedical engineering practice or research. The Master of Science requires a thesis and can serve as a terminal degree for students interested in an in-depth specialization.

The Master of Engineering in Biomedical Engineering and the Master of Engineering in Clinical Engineering are non-thesis graduate degrees and normally considered to be terminal professional degrees. The clinical engineering Master of Engineering program is for those individuals primarily interested in employment in hospitals or other clinical environments. This subspecialty involves a close interaction with patients and the health care delivery system and an internship experience is required of all students.

### 1.2.3. Combined Bachelor's of Science (BS) / Master's Degree Program

The goal of the Combined BS/Master's Degree Program is to allow qualified WPI undergraduate students to obtain a cost-effective and time-efficient advanced degree in BME, while at the same time enhancing the quality of the graduate program by attracting WPI's most talented undergraduates. It affords an opportunity for outstanding WPI undergraduate students to earn both a Bachelor's degree and a Master's degree in BME from WPI concurrently and in less time than would typically be required to earn each degree separately. The principal advantage of this program is that it allows for certain courses to be counted towards both degree requirements, thereby reducing total class time. With careful planning and motivation, this program typically allows a student to complete the requirements for both degrees with only one additional year of study (5 years total). However, because a student must still satisfy all graduate degree requirements, the actual time spent in the program may be longer than 5 years. There are two degree options for students: a thesis-based Master of Science (BS/MS) option and a non-thesis Master of Engineering (BS/ME) option.

### 1.2.4. Graduate Certificate Program

A Graduate Certificate in Biomedical Engineering is intended for individuals wishing to pursue graduate course work, with the benefit of academic advising, but without the commitment to a full graduate degree program. It affords an opportunity for students holding an undergraduate degree in engineering or science

to continue their study in BME. The program requires a student to complete four to five thematically related courses, with the program of study approved by an academic advisor. The BME Department currently offers a Graduate Certificate in the area of *Medical Instrumentation and Devices*.

### **1.2.5. Advanced Study for Non-Degree Students**

Courses in biomedical engineering are available for students who do not wish to commit themselves to any degree or certificate program but who wish to enroll in a single course or a limited number of courses in a specialized field. Up to three courses in biomedical engineering can be taken as a non-matriculated graduate student and subsequently applied to a graduate degree program at WPI.

## **2. Joint WPI / UMMS PhD Degree Program**

### **2.1. Admission Requirements and the Application Process**

#### **2.1.1. Admission Requirements**

Applicants are expected to have an undergraduate degree and a strong background in engineering, life sciences, and mathematics and to achieve basic and advanced knowledge in engineering, life sciences, and biomedical engineering. Students are also expected to have had one semester of organic chemistry, a full year of biology, and mathematics through differential equations. Admission normally requires a minimum GPA of 3.2 (out of 4.0) and a minimum quantitative score of 700 on the Graduate Record Examination (GRE). The combined verbal and quantitative score should be at least 1200.

#### **2.1.2. Application Procedure**

Application to the program can be made either through the Office of Graduate Studies and Enrollment (GSE) at WPI or the GSBS Office at UMMS. Details on the application process to either school are given below.

##### **2.1.2.1. Application through WPI**

The Office of GSE (phone: 508-831-5301, email: [gse@wpi.edu](mailto:gse@wpi.edu), <http://grad.wpi.edu>) accepts both online and paper applications. Online applications are preferred. Requirements for admission include submission of the following:

- A completed *Application for Admission to Graduate Study at WPI*.
- A nonrefundable application fee (waived for WPI alumni).
- Official college transcripts from all accredited degree-granting institutions attended. Admission normally requires a minimum GPA of 3.2 (out of 4.0).
- Three letters of recommendation from individuals who can comment on the qualifications relevant to the applicant's admission. For recently graduated students, a majority of these references should be from faculty.
- Official GRE scores for the General Test. Admission normally requires a minimum quantitative score of 700. The combined verbal and quantitative score should be at least 1200.
- TOEFL (Test of English as a Foreign Language) scores must be submitted by all foreign applicants (waived for foreign students presently attending a U.S. school). TOEFL scores are only valid for two years. A minimum score of 550 (600 for Joint PhD Program) on the paper exam or 213 on the computer-based exam is required.
- Statement of Purpose. This is a brief essay discussing background, interests, *academic intent*, and the reasons the applicant feels he/she would benefit from the Joint PhD Program in Biomedical Engineering and Medical Physics.

Applicants must observe the application and financial aid deadlines imposed by the GSE. BME Program Faculty from WPI and UMMS review complete applications received by the GSE. Incomplete applications are not generally reviewed.

##### **2.1.2.2. Application through the University of Massachusetts Medical School (UMMS)**

Application to the program may be made through the GSBS at UMMS (phone: 1-888-860-2334, <http://www.umassmed.edu/gsbbs>). Requirements for admission include submission of the following:

- A completed UMMS *Graduate School of Biomedical Sciences Application for Admission* form.
- A nonrefundable application fee.
- Complete official transcripts for all undergraduate and graduate institutions attended. Admission normally requires a minimum GPA of 3.2 (out of 4.0).
- Three letters of recommendation from individuals who are able to assess your academic performance and prospective success in graduate-level work. For recently graduate students, a majority of these references should be from faculty.
- Official GRE scores for the General Test. Admission normally requires a minimum quantitative score of 700 on the GRE. The combined verbal and quantitative score should be at least 1200.
- TOEFL scores must be submitted by all foreign applicants. A minimum score of 600 on the paper examination is required.
- Personal Statement. This is a brief essay discussing background, interests, academic intent, and the reasons the applicant feels he/she would benefit from the Joint PhD Program in Biomedical Engineering and Medical Physics.

Applicants must observe the application and financial aid deadlines imposed by the GSBS. BME Program Faculty from WPI and UMMS review complete applications received by the GSBS. Incomplete applications are not generally reviewed.

### **2.1.3. Financial Aid**

Institutional stipend and tuition support from WPI and UMMS is generally guaranteed for the first two years in the program. Therefore, a decision on admission and financial aid are made simultaneously. Subsequent years of support for a student in the Joint PhD Program are derived from the student's Research Advisor.

### **2.1.4. Provisional Admission**

- The Joint PhD Program does not admit students provisionally.

## **2.2. Summary Degree Requirements**

Students in the Joint PhD program must simultaneously satisfy the following degree requirements:

- WPI's General Requirements for All Advanced Degrees.
- WPI's General Requirements for the PhD Degree.
- Requirements for the PhD Degree of the GSBS at UMMS.
- The BME Program's Specific Requirements for the Joint PhD Degree.

The first two institutional degree requirements are summarized below and detailed in the WPI Graduate Catalog. The GSBS institutional degree requirements are summarized below and detailed in the Faculty/Student Handbook for the GSBS at UMMS.

The BME Program's specific degree requirements are explained fully in this chapter of the Handbook. These program requirements have been structured to incorporate all institutional degree requirements, so that satisfying the BME Program's degree requirements for the PhD will also satisfy the institutional degree requirements from WPI and UMMS. All degree requirements must be satisfied before the degree is awarded.

### **2.2.1. Institutional Degree Requirements**

#### **2.2.1.1. WPI's General Requirements for all Advanced Degrees**

All students in the Joint PhD program must satisfy the following:

- At the time the degree is awarded, the student must have been admitted to the Joint PhD program in Biomedical Engineering and Medical Physics.
- A minimum of two-thirds of the required graduate credit for an advanced degree must have been earned at WPI or UMMS (in the GSBS).
- The student must have a program GPA of 3.0 or greater for courses taken at WPI and GSBS.

- The student must satisfy the graduate rules in effect at a specific date between their matriculation date and their graduation date. In applying for graduation (the WPI Graduate Student *Application for Graduation*), the student must specify, by year, which WPI Graduate Catalog contains the rules being satisfied.

After the WPI *Application for Graduation* is submitted, all advanced degrees are subject to the final approval of the Committee on Graduate Studies and Research (CGSR) at WPI, which determines if the student has satisfied the letter of intent of the requirements for the PhD. The CGSR makes its recommendations for the approval of the PhD to the WPI faculty, which in turn recommends to the President and Trustees for their final approval the names of students who should be awarded the doctorate in biomedical engineering.

### **2.2.1.2. WPI's General Requirements for the PhD Degree**

All students in the Joint PhD program must satisfy the following:

- The student must demonstrate to the faculty high academic attainment and the ability to conduct original independent research.
- The student must complete a minimum of 90 credit hours of graduate work beyond the bachelor's degree, or a minimum of 60 credit hours of graduate work beyond the master's degree, including in either case at least 30 credit hours of thesis research.
- The student must establish residency by being a full time graduate student for at least one continuous academic year (Note: The BME Program's Specific Requirements for the PhD Degree requires a full-time effort for a minimum of at least three years, which is longer than that specified by WPI).
- The student must attain status as a PhD candidate by satisfying the BME Program's Specific Requirements for the Joint PhD Degree.
- The student must prepare a PhD dissertation, and defend it before a Dissertation Committee (the PhD Dissertation Examination), at least two of whose members must be from the PhD Program in BME, and at least one of whose members must be from outside the PhD Program in BME. After a successful defense, determined by a majority vote in the affirmative by the Dissertation Committee, the dissertation must be endorsed by those members of the Dissertation Committee who voted to approve it. The completed dissertation must follow in format the instructions published by the WPI library. After final approval for format of the dissertation, the Associate Provost for Academic Affairs will notify the registrar that the dissertation has been approved.
- Once the student has satisfied the BME Program's candidacy requirements (see below), the student will be permitted to enroll for dissertation credits. Prior to the completion of all candidacy requirements, a student may enroll for no more than 18 credits of directed research.

### **2.2.1.3. Requirements for the PhD Degree of the Graduate School of Biomedical Sciences (GSBS) at UMMS**

All students in the Joint PhD program must satisfy the following:

- Pass the core requirements and all graduate courses and laboratory rotations required by the Joint PhD Program (Note: the term "core requirements" does NOT necessarily mean the Biomedical Science Core of the GSBS for Joint PhD Program students).
- Pass the PhD Qualifying Examination.
- Fulfill the teaching requirement.
- Write a PhD Dissertation on the student's original research.
- Pass the final PhD Dissertation Examination.

All advanced degrees are subject to final administrative approval by the Dean of Graduate Studies at UMMS.

### **2.2.2. Summary of the BME Program Requirements for the Joint PhD Degree**

While a complete description of the BME Program's requirements for the PhD degree are provided later in this chapter, the following is a summary of these requirements. All students in both PhD Programs must satisfy the following:

- Pass the course requirement, including required laboratory rotations.
- Pass the PhD Qualifying Examination.
- Fulfill the teaching requirement.
- Fulfill the seminar requirement.
- Fulfill the residency requirement.
- Write a PhD Dissertation on the student's original research.
- Pass the final PhD Dissertation Examination.

### **2.2.3. Exceptions and Petitions for Change**

Exceptions to general and specific degree requirements or to other rules may be made, but only by written petition to the CGSR at WPI and simultaneously to the Dean of the GSBS. A petition to CGSR and the Dean of GSBS should be initiated by the student and may be supported by the BME Program Steering Committee.

## **2.3. Committees and Advising**

### **2.3.1. Overview**

Various committees and advisors are charged with monitoring and directing the progress of students in the Joint PhD program. These committees and advisors are summarized below:

- Academic Advisory Committee – An *ad hoc* committee formed to provide the student with counsel and information during the early years in the Program. This committee advises the student from entry into the Program until: 1) completion of the laboratory rotations; 2) a Research Advisor has been selected; and 3) the student is ready for the PhD Qualifying Examination.
- Qualifying Examination Committee – An *ad hoc* committee formed to administer the PhD Qualifying Examination to the student.
- Research Advisory Committee – An *ad hoc* committee formed to advise the student from the time that the Academic Advisory Committee has formally decided that the student is ready for the PhD Qualifying Examination until the student has submitted the completed dissertation.
- Dissertation Examination Committee – An *ad hoc* committee formed to administer the PhD Dissertation Examination to the student.
- Research Advisor (Dissertation Mentor) – A BME Program Faculty Member charged with mentoring and supporting the dissertation research project.
- Joint Program Steering Committee – A committee responsible for administering the Joint PhD Program (see Section 2.3.8 for details).

In the sections that follow on the various committees, the following definition holds:

- BME Program Faculty Member – a faculty member holding a primary appointment at WPI or the GSBS and formally approved by the Joint Program Steering Committee (see Section 2.3.8 for details). Only a BME Program Faculty Member may serve as Research Advisor (Dissertation Mentor).

### **2.3.2. Standards for All Committees**

The Chair for each committee shall keep records of all meetings and send copies of the records to other committee members and, after their approval, to the Joint Program Steering Committee. The Joint Program Steering Committee shall distribute the records, after checking them for compliance with the rules and regulations, to the student and a copy shall be kept in the student's file(s). Students have two identical student files, one in the Department of Biomedical Engineering at WPI and the other in the GSBS Graduate Office at UMMS.

### **2.3.3. Academic Advisory Committee**

Each student entering the Joint PhD Program is advised by an Academic Advisory Committee. This committee meets with the student at least twice yearly, normally just before each academic semester.

#### **2.3.3.1. Duties of the Academic Advisory Committee**

- Meet with the incoming PhD student during the orientation period to go over *this* Handbook in detail, making sure that everyone understands his/her responsibilities.
- Provide the student with counsel and information.
- Assist the student in selecting a sequence of coursework and laboratory rotations.
- Advise the student in the selection of a Research Advisor.
- Assess progress and approve alterations in proposed course work and laboratory rotations.
- Provide a written report of the student's status to the Joint Program Steering Committee following each meeting.
- May serve as the evaluating committee for the student's Teaching Requirement.

#### **2.3.3.2. Structure and Formation of the Committee**

The committee shall be appointed by the Joint Program Steering Committee based on the student's background and research interests and shall consist of a Chair and one or two additional members. All members of the committee must be BME Program Faculty. To best advise students, one member should be from WPI and another member should be from the GSBS.

### **2.3.4. Qualifying Examination Committee (QEC)**

Upon recommendation by the Academic Advisory Committee and based on the student's background and research interests, a QEC shall be appointed to administer the PhD Qualifying Examination.

#### **2.3.4.1. Duties of the QEC**

- Review the academic record of the candidate.
- Advise the student on preparation for the PhD Qualifying Examination.
- Conduct the examination. The student passes the qualifying examination if at least four of the five committee members vote approval.

#### **2.3.4.2. Structure and Formation of the Committee**

At or near the completion of course work and laboratory rotations, the student's Academic Advisory Committee shall recommend to the Joint Program Steering Committee that the student take the PhD Qualifying Examination. The Joint Program Steering Committee shall then appoint a QEC of one Chair and four additional members, taking into account the recommendations of the Academic Advisory Committee. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least two other members shall be BME Program Faculty.
- At least one BME Program Faculty member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI.
- At least one BME Program Faculty member must hold a primary faculty appointment in the GSBS.
- At least one member shall be a WPI or GSBS faculty member not associated with the Joint PhD Program.
- The student's prospective Research Advisor shall not be a member of this committee. He/she may be present at the examination, but shall not participate in the questioning and shall not be present during discussion and vote on the student's performance.

### **2.3.5. Research Advisory Committee**

This committee shall advise the student from the time that the Academic Advisory Committee has decided that the student is ready for the PhD Qualifying Examination until the student has submitted the completed dissertation. The committee shall meet at least once per semester and whenever requested by the Chair, the student, or the Joint Program Steering Committee.

### **2.3.5.1. Duties of the Research Advisory Committee**

- Serves in an advisory capacity to the student.
- Evaluates and approves a written dissertation proposal presented to it by the student.
- Reviews and advises on research progress.
- Determines when the student is ready to begin writing the dissertation.
- Monitors the progress of writing the dissertation.
- Serves in an advisory capacity to the student and Research Advisor if any conflicts arise between the Research Advisor and the student, in which case the mentor excuses him/herself from the committee proceedings.
- May serve as the evaluating committee for the student's Teaching Requirement.

### **2.3.5.2. Structure and Formation of the Committee**

The committee shall be appointed by the Joint Program Steering Committee upon the recommendation of the Research Advisor and shall consist of a Chair (usually the Research Advisor) and two or more additional members who can best judge the research. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least two other members shall be BME Program Faculty.
- At least one member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI.
- At least one member must hold a primary faculty appointment in the GSBS.

### **2.3.6. Dissertation Examination Committee**

Upon recommendation by the Research Advisory Committee, a Dissertation Examination Committee shall be formed to administer the PhD Dissertation Examination.

#### **2.3.6.1. Duties of the PhD Dissertation Examination Committee**

- Conduct the examination. The student passes the dissertation examination if a majority of the committee members vote approval. After a successful defense, those members who voted to approve it must endorse the dissertation.

#### **2.3.6.2. Structure and Formation of the Committee**

The student's Research Advisory Committee shall recommend to the Joint Program Steering Committee that the student take the PhD Dissertation Examination. The BME Steering Committee shall then appoint a Dissertation Examination Committee of a Chair and at least four additional members, taking into account the recommendations of the Research Advisory Committee and the Research Advisor. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least two other members shall be BME Program Faculty.
- At least one BME Program Faculty member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI.
- At least one BME Program Faculty member must hold a primary faculty appointment in the GSBS.
- At least one member shall be a WPI or GSBS faculty member not associated with the BME Program.
- At least one member shall be from an institution other than WPI or UMMS. This member normally attends the examination; in unusual circumstances, the outside examiner will be exempt from attending but shall then submit a written report on the dissertation.

#### **2.3.6.3. Rules and Responsibilities for the PhD Dissertation Examination**

- The Chair sets the date of the examination and oversees the examination and all meetings of the committee.

- Committee members shall receive a copy of the Dissertation after the Research Advisor has approved it. This copy must be essentially in its final form, pending any changes required by the committee.
- Committee members must receive the dissertation at least 14 days before the date of the scheduled examination.
- Committee members must report to the Chair at least 48 hours before the examination if they find the dissertation to be in an inadequate form to proceed with the oral dissertation examination.
- The Chair reports at least 24 hours before the examination to the other committee members, the student, and the Joint Program Steering Committee if a committee member finds the dissertation to be in an inadequate form to proceed with the oral dissertation examination.
- Committee members approve and sign the final copy of the dissertation. The Chair designates one committee member to supervise that any alterations of the dissertation be completed before submission to the Joint Steering Committee. He/she shall not sign the Dissertation until all of these corrections/alterations are completed.
- The Chair reports in writing to the Joint Program Steering Committee the results of the examination and the decision of the committee.
- The Dean of the GSBS at UMMS must administratively approve all dissertations.

### **2.3.7. Research Advisor (Dissertation Mentor)**

The student selects a Research Advisor (or Dissertation Mentor) upon completion of all laboratory rotations. The Research Advisor must be an approved BME Program Faculty Member and must agree to mentor the student.

#### **2.3.7.1. Duties of the Research Advisor**

- Must demonstrate a reasonable ability to provide adequate financial support for conducting the research project and supporting the student.

### **2.3.8. Joint Program Steering Committee**

The Joint Program Steering Committee is responsible for administering the Joint PhD Program in Biomedical Engineering and Medical Physics. It acts as a liaison between the faculty and students in the program and the administrative structures at WPI and the GSBS.

#### **2.3.8.1. Duties of the Joint Program Steering Committee**

- Oversees and administers the Joint PhD Program.
- Appoints WPI and GSBS faculty as BME Program Faculty Members.
- Appoints BME Program Faculty Members to a student's Academic Advisory Committee based on the student's background and research interests.
- Appoints faculty to a student's QEC based on the student's background and research interests and the recommendations of the student's Academic Advisory Committee.
- Based upon the recommendations of the student's Research Advisor, appoints faculty to a student's Research Advisory Committee.
- Based upon the recommendations of the Research Advisory Committee, appoints faculty to a student's Dissertation Examination Committee.
- Appoints BME Program Faculty Members to different sub-committees, including the Admissions Committee.
- Monitors the progress of students in the Joint PhD Program.
- Acts on admission of students in the Joint PhD Program to degree candidacy.
- Acts on student and faculty petitions on academic matters.

## 2.4. Course Requirement

Because research in the field of biomedical engineering requires a solid working knowledge of a broad range of subjects in the life sciences, engineering, and mathematics, course credits must be distributed across the following categories with the noted minimums:

- Biomedical Engineering (12 credits)
- Life Sciences (9 credits) – All life science courses must be taken in the GSBS at UMMS and must include two blocks of the Biomedical Sciences Core (Block I and III recommended) and Physiology.
- Advanced Engineering Mathematics (3 credits)
- Statistics (3 credits)
- Laboratory Rotations (6 credits) – At least one rotation must be at WPI and one must be at UMMS.
- Responsible Conduct of Science (1 credit)
- Advanced Courses and Electives (12 credits)
- Dissertation Research (30 credits)

The student's Academic Advisory Committee may require additional course work to address specific deficiencies in the student's background. Up to 9 credits at the advanced undergraduate level (4000-level) may be used to satisfy these course requirements.

### 2.4.1. Standards for Course Grades

- Students must maintain a GPA of at least 3.0 on a scale of 4.0, where A = 4.0, B = 3.0, C = 2.0, D = 1.0, and F = 0.0. A grade of Pass does not count toward the GPA.
- Students may have a C grade in at most two courses for credit to count towards the PhD, and for no more than 6 credits; no D or F grades are allowed. Students who attain a grade of C in a Biomedical Sciences Core block must repeat this block and achieve at least a grade of B.
- Students whose GPA is below 3.0 may be placed on probation. Achievement of a cumulative average of 3.0 or better during the following semester will return a student to good standing.
- Students on probation for two consecutive semesters or who have grades of C in more than two courses, or have any D or F grades, will be dismissed from the program, except in rare extenuating circumstances.

### 2.4.2. Seminar Requirement

The Joint PhD Program requires that all students attend weekly seminars and, in addition, present a seminar once a year. To facilitate this process, students must enroll in the class *BME 591 – Graduate Seminar*. All PhD students are required to pass BME 591 four times. This graduate course is graded pass/fail for zero credits.

### 2.4.3. Typical Curriculum

The following are representative examples of course work for different specializations in the PhD Program.

#### 2.4.3.1. Bioinstrumentation/Biosensor Specialization

#### 2.4.3.2. Biomechanics/Biomaterials Specialization

#### 2.4.3.3. Biomedical Imaging Specialization

#### 2.4.3.4. Tissue Engineering

## 2.5. Laboratory Rotations

Students are required to participate in at least two different laboratory rotations during their first two years in the Joint PhD Program. Laboratory rotations – short periods of research experience under the direction of WPI or GSBS faculty members – are intended to familiarize students with concepts and techniques in several different engineering and scientific fields. They allow faculty members to observe and evaluate the research aptitudes of students and permit students to evaluate the types of projects that might be developed into dissertation projects. Upon completion of each rotation, the student submits a written report on the

research accomplished. The faculty sponsor grades the rotation on a Pass/Fail basis and submits a written evaluation of student performance to the Joint Program Steering Committee. Each rotation is a three- or four-credit course and lasts a minimum of eight weeks if the student participates full time in the laboratory, or up to a full semester if the student takes courses at the same time.

### **2.5.1. Standards for Laboratory Rotations**

- The choice of rotations is made in consultation with and approved by the student's Academic Advisory Committee.
- Rotations shall be taken only with WPI or GSBS faculty members (Note: Dissertation projects can only be taken with approved BME Program Faculty and not all WPI or GSBS faculty members are BME Program Faculty).
- At least one rotation shall be completed on the WPI campus with a WPI faculty member and at least one rotation shall be completed on the UMMS campus with a GSBS faculty member.
- A rotation should be considered equivalent to a course with a similar commitment of both student and faculty.
- All rotations begin on the first day of class; either fall, spring, or summer semester. During the first 18 months in the Program, two full-semester rotations must be taken. Double rotations (two one-half rotations per semester) may be taken as long as the two full-semester rotation requirement is fulfilled.
- The student will prepare a written report on his or her rotation. The report should be a 1-2 page (maximum) summary of the project and the research experience. Primary data, figures, tables, etc. are not required or expected. A report is required for all rotations, regardless of length. The report should be submitted to the Principal Investigator (PI) and to the Joint Program Steering Committee within 2-3 weeks after completion of the rotation. The research summary should be reviewed by the PI for the benefit of the student. However, formal evaluation of the research summary by the PI is not expected. The research summary is to become part of the student's permanent record. Students will not be permitted to take the qualifying examination unless all research summaries are present in the permanent record(s) at WPI and the GSBS.
- Students will be given three credits for full fall or spring rotations (double one-half rotations will receive 1.5 credits each). The rotation is expected to occupy a minimum of 12 hours per week during the academic year. The student will be given 4 hours credit for the full summer rotation (or 2 credits each for double one-half rotations). Students should take no more than 9 other credits simultaneously with a rotation during the fall and spring semesters. Students may take additional rotation periods in the same laboratory, but must rotate through 2 different labs to satisfy the rotation requirement.
- Faculty members must provide to the students an explanation of the rotation projects, its goals, and an estimation of the time commitment.
- The student shall receive a pass / fail grade for the rotation. Faculty members may provide a written evaluation of the student at the end of the rotation – to be made available to the student. The student will have an opportunity to discuss this evaluation with the faculty member before it is sent to the Joint Program Steering Committee. The student may choose to provide an accompanying evaluation of his or her laboratory experience with the faculty member's evaluation.

### **2.6. PhD Qualifying Examination**

Students are required to pass a PhD Qualifying Examination no later than the start of the third year after formal admittance to the PhD program. This examination is a defense of an original research proposal, either: 1) related to a student's dissertation topic or 2) outside the area of the student's prospective dissertation topic, made before a committee representative of the area of specialization. The examination is used to evaluate the ability of the student to pose meaningful engineering and scientific questions, formulate scientific hypotheses to propose experimental methods for answering those questions, and to interpret the validity and significance of probable outcomes of these experiments. It is also used to test a

student's comprehension and understanding of their formal course work in the life sciences, biomedical engineering, and mathematics.

### **2.6.1. Standards for the PhD Qualifying Examination (QE)**

- The requirement to take the QE is adequate prior academic performance in the Core Curriculum and Advanced Topics (only 1 remediated 'C' is permitted).
- The administration of a PhD QE constitutes acceptance of the student by the Biomedical Engineering Program, which implies the availability and willingness of one or more Research Advisors.
- All PhD students must pass their QE before the start of their third year of formal course work or they will be subject to dismissal from the Program.
- A student passes the PhD QE if at least four of the five members of the QEC vote approval. The Committee may also provisionally pass a student and then set the conditions (i.e. additional courses) necessary for removing the provisional status.
- If a student fails the examination, only extraordinary circumstances will dictate the administration of a second examination. Only one repeated examination may be held upon the request of the PhD QEC and with the concurrence of the Joint Program Steering Committee.
- If a student fails to pass the examination on the second attempt and does not have a master's degree in biomedical engineering from WPI, the QEC has the option of allowing the student to attempt a Master of Science (MS) in BME or meet the Master of Engineering (ME) degree requirements. If the student meets the requirements for the MS or ME degree, it will be granted as a terminal degree from WPI.

### **2.6.2. Format and Timetable of the Examination**

- The QE shall be of the research proposal type. The student shall choose either: 1) a research problem related to their dissertation or 2) one or more research problems not related to his/her dissertation research. The student will first prepare a one-page abstract describing an experimental approach to their proposed qualifying exam problem for review by the members of the QEC.

### **2.6.3. Abstract development**

- The student and Thesis Research Advisor determine the topic of the QE proposal. This may include the anticipated area of thesis research.
- Prior to selection of a thesis research lab or program, the student may request clarification in writing of specific programmatic QE requirements (permissible proposal research areas and formats) from both the Thesis Advisor and Biomedical Engineering Graduate Program Committee Chairman.
- The Qualifying Proposal is intended to develop and showcase the scientific skills of the student. While interactions with the student's Thesis Advisor are encouraged, plagiarism will result in dismissal from the Program.

#### **2.6.3.1. Thesis research-based proposal**

- The student and Thesis Advisor recommend a Thesis Research Advisory Committee (TRAC) based on the proposed research area. The Thesis Advisor is an ex officio member of the TRAC. The appointment of the TRAC is the responsibility of the Biomedical Engineering Graduate Program Committee Chairman.
- The student develops the abstract and is required to defend the abstract orally before the TRAC.
- The Thesis Advisor may attend this defense but as an observer only.
- Student submits approved final abstract for advertisement of proposal presentation no later than 1 week following receipt of abstract approval by the TRAC.
- This defense represents an opportunity for the student to prepare for the full QE.

- The Chair of the TRAC summarizes the outcome and expectations in writing to the student and TRAC.

### **2.6.3.2. Non-Thesis research-based proposal**

- The Biomedical Engineering Graduate Program Committee Chairman selects a QEC. This may include the Thesis Advisor.
- The student develops an abstract and defends the abstract orally before the QEC.
- Student submits approved final abstract for advertisement of proposal presentation no later than 1 week following receipt of abstract approval by the QEC.
- The Thesis Advisor may attend this defense but as an observer only.
- This defense represents an opportunity for the student to prepare for the full QE.
- The Chair of the QEC summarizes the outcome and expectations in writing to the student and QEC.

### **2.6.4. Qualifying exam proposal procedures**

- With the approval of the abstract by the QEC, the student shall then prepare a written research proposal on the problem approved by the committee.
- The purpose of the qualifying exam is to assess and further prepare the student for thesis research.
- The proposal should be in NIH grant format and should include a review of the relevant literature, a clear statement of the problem, a research plan, and justification of the research plan. It should also include all proposed experiments, along with interpretations of probable outcomes of the experiments described.
- The student will develop a detailed research proposal in NIH grant format in a given area that identifies:
  - 1) The problem/hypotheses to be tested;
  - 2) Why the problem is important;
  - 3) How the hypotheses will be tested and why each specific approach is selected;
  - 4) What other approaches might be used (if any);
  - 5) Expected results and interpretation; and
  - 6) What future experiments will be done should the hypothesis stand or fail.
- The BME Departmental Office at WPI and the GSBS Graduate Office at UMMS shall appropriately publicize the PhD QE public seminar at least 7 days prior to the examination date.

### **2.6.5. Oral defense of proposal**

- The written research proposal shall be given to the QEC at least 10 days before the examination, at which time the student will present and defend this proposal.
- The student will first present a 30 – 50 minute public seminar on the proposal and then defend it before the PhD QEC.
- The Committee may ask questions on any subject with which the student should be familiar, whether or not it is related to the research proposal(s). This includes all course work that the student has taken while in the PhD program.
- The committee decides whether the student has sufficient ability and preparation to undertake independent research leading to a PhD degree.

#### **2.6.5.1. Thesis research-based oral defense of proposal**

- Student submits written proposal within 5 weeks of abstract approval.

- Two weeks later, student defends their proposal orally before the TRAC.
- The Thesis Advisor cannot be present.

#### **2.6.5.2. Non-thesis research-based oral defense of proposal**

- Student submits written proposal within 5 weeks of abstract approval.
- Two weeks later, student defends proposal orally before the QEC.
- The Thesis Advisor may attend this defense but as an observer only.

#### **2.6.5.3. Nature of the examination**

- The TRAC or QEC may ask any questions pertaining to the proposed research.
- These questions must challenge the proposed hypotheses and the rationale, strategy and technical details of the proposed experiments.
- The student must demonstrate a thorough understanding of the proposed data collection and analysis procedures and must be aware of alternative approaches that might be used to answer the problem.
- The student must be able to interpret expected and unexpected findings within the context of the method of data collection, the tested hypotheses and the broader field.
- The TRAC or QEC may also ask general questions as they relate to the proposed field of study. These questions must be drawn from the student's Core curriculum and Advanced Topics curriculum.

#### **2.6.5.4. Outcome - Pass/Fail, revise or retest**

- **Pass** - Enter full thesis research
- **Fail** - Academic withdrawal from the Biomedical Engineering Program.  
The student may discuss the outcome of their Qualifying Exam with the Chairman of the Biomedical Engineering Program and request a review of the result. If so requested, the Chairman of the Biomedical Engineering Program will discuss the proceedings of the exam with the Chair and committee members of the QEC. The Chairman of the Biomedical Engineering Program will discuss the student's performance and potential in the lab setting with the student's Ph.D. mentor and will review the student's academic performance. The Chairman of the Biomedical Engineering Program will issue a finding which is final.
- **Revise** – The TRAC or QEC summarizes in writing the areas of weakness in the oral defense proposal. The student must address these specific points by rewriting the relevant sections of the written proposal. These revisions must be completed within 2 weeks of receipt of the critique. The TRAC or QEC will then evaluate the final proposal and assign a grade of Pass or Fail.
- **Retest** - The TRAC or QEC summarizes in writing the areas of weakness in the oral defense/proposal. The student must address these specific points by rewriting the relevant sections of the written proposal and submitting it to a second oral defense. These revisions and the retest must be completed within 3 weeks of receipt of the critique. The RAC or QEC will then evaluate the oral defense and assign a grade of Pass or Fail.
- **Note:** It may be recommended or required by either the QEC or the TRAC that the student takes additional course(s) to correct a deficiency. If required, the student must register in the specific course for credit. A grade of 'F' or 'C' in the course(s) will result in academic withdrawal from the Biomedical Engineering Program.

### **2.7. Admission to Candidacy**

Formal admission to candidacy in the Joint PhD Program is conferred upon students who have completed their core course work (exclusive of thesis research) and laboratory rotation and passed the PhD QE. With

candidacy, the student will be permitted to enroll for dissertation credits. Prior to completion of the candidacy requirements, a student may enroll for no more than 18 credits of directed research (BME 598).

## **2.8. PhD Dissertation Proposal**

The PhD Dissertation Proposal is a written document prepared and defended before the student's Research Advisory Committee. Formal acceptance of student's dissertation research program follows the approval of this proposal. The proposal should not be thought of as an examination. Rather, it serves two very important functions:

- An accepted proposal provides a guarantee to the student that the Research Advisory Committee found the proposed research program acceptable.
- It provides the student with important feedback on his/her proposed research. Although the Research Advisor will certainly provide the student with the most valuable advice, the Research Advisory Committee can also provide additional insights and feedback.

### **2.8.1. Standards for the PhD Dissertation Proposal**

- The proposal should be presented within one calendar year of taking the PhD QE or as soon as a line of research has been defined and there is evidence that the experimental protocols can be carried out.
- The proposal must be formally approved by the Research Advisory Committee before the student can formally begin writing the actual PhD Dissertation Document.
- The proposal is approved if a majority of the Research Advisory Committee members vote approval. Generally, most proposals are approved. If the line of research proposed is too distant from what the Research Advisory Committee considers "Biomedical Engineering" or, more often, if the hypotheses to be tested are not stated clearly enough, the student will be asked to resubmit the proposal.

### **2.8.2. Format and Timetable for the Proposal**

- The written proposal should be in the form of an NIH grant request and should be cast in the form of hypotheses-testing, not fact gathering. The proposal should include the Specific Aims, Background and Significance, Preliminary Results, and Methods. It need not include the Budget.
- The student presents the proposal orally at a scheduled Research Advisory Committee meeting. The written PhD Dissertation Proposal shall be given to the Research Advisory Committee at least 10 days before this meeting. The student will be expected to speak for no longer than 30 minutes and the Committee will probably spend about 30 minutes asking questions. The committee then decides in a closed session whether the student has successfully defended his/her proposal.

## **2.9. PhD Dissertation Document and Defense**

All PhD students must prepare a dissertation document and defend it before a Dissertation Examination Committee. For this requirement, PhD program students must:

- Present a one-hour public seminar (PhD Dissertation Seminar or Oral Defense) on the results of the completed dissertation project.
- On the same day, successfully pass the PhD Dissertation Examination.
- Present an acceptable and appropriately signed dissertation to the BME Steering Committee. Administrative approval by this committee constitutes acceptance of the dissertation.
- Present an acceptable and appropriately signed dissertation to the Dean of the GSBS at UMMS for administrative approval. The approval of the Joint Steering Committee is required before submission to the Dean.

### **2.9.1. PhD Dissertation Seminar (Oral Defense)**

The BME Departmental Office at WPI and the GSBS Graduate Office at UMMS shall appropriately publicize the dissertation seminar at least 14 days prior to the examination date. The seminar shall be of the standard research seminar format and shall be limited to approximately one hour; it forms an integral part of the examination.

### **2.9.2. PhD Dissertation Examination**

Following the PhD Dissertation Seminar, the student must defend the dissertation before the Dissertation Examination Committee. The student successfully passes the examination if a majority of the committee members vote approval. If the student does not pass the examination, the Committee shall make a recommendation to the BME Steering Committee. This recommendation may include:

- Rewriting the dissertation or part of it.
- Doing additional experimental or theoretical work on the dissertation subject.
- Studying background material pertaining to the field of specialization.
- Presenting another seminar.
- Being awarded a Master of Science (MS) degree or Master of Engineering (ME) degree from WPI for coursework and research completed.

### **2.9.3. PhD Dissertation Document**

A copy of the dissertation, which must be given to all Dissertation Examination Committee members, shall:

- Be a finished product and approved by the Research Advisor.
- Conform to the dissertation standards of WPI and the University of Massachusetts.

The dissertation must contain:

- A concise, but comprehensive, *Introduction*.
- A concise, but comprehensive, *Discussion* relating the results presented to the current and future state of the field.
- Intervening pages consisting of either: (i) *Materials and Methods*, and *Results* section or, (ii) the text of a series of articles in manuscript form published in or ready to be submitted to peer-review Journals with the candidate as first author. Work conducted by someone other than the student must be clearly identified and referenced as such in the dissertation.
- A comprehensive *Bibliography*.
- An *Abstract*.
- Figures of a quality suitable for publication.

After successful completion of the PhD Dissertation Examination, the PhD dissertation document shall be:

- Revised and corrected according to the decisions of the examination committee.
- Signed by all committee members who voted approval of the document and the Research Advisor.
- Submitted to the BME Steering Committee for administrative approval.
- Submitted to the Dean of the GSBS at UMMS for administrative approval (for students in the Joint PhD Program only).
- Submitted in a format suitable for archiving and storage. Students must follow the regulations for preparation of dissertations published by the library at WPI. For students in the Joint PhD Program, the regulations of the GSBS library must also be followed.

Please note that PhD students must be registered at WPI for 3 semester credit hours in the semester that the degree requirements are completed.

## **2.10. Teaching Requirement**

All candidates for the PhD degree must demonstrate teaching skills by preparing, presenting, and evaluating a teaching exercise. This experience may involve a research seminar, lecture, demonstration, or conference in the context of a medical school basic science course or BME course at WPI. Formal parts of the presentation may be videotaped as appropriate. The presentation and associated materials are critiqued and evaluated by program faculty members. The student's academic advisory committee is responsible for evaluating the teaching exercise based on criteria previously defined. The teaching requirement can be fulfilled at any time and there is no limit to the number of attempts a student may make to fulfill this requirement. It must, however, be completed successfully before the dissertation defense can be held.

## **2.11. Residency Requirement**

The PhD program requires a full-time effort for a minimum of at least 3 years. An explicit and detailed definition of "full-time" status is given in the WPI Graduate Catalog.

## **2.12. Combined Master's of Engineering (ME) / PhD Degree**

Most PhD students that do not start with a master's degree in biomedical engineering will, within 2-3 years of study, satisfy all the requirements for the Master's of Engineering (ME) degree in BME. Upon written request to the BME Steering Committee, students who qualify will be awarded a ME degree in recognition of their achievements. Earning this degree will not change any of the PhD requirements. Students should note that PhD dissertation credits do not count towards this degree. The required credits for the ME degree may be based on directed research credits (BE 598).

## **3. PhD Degree Programs**

There are two PhD degree programs in BME: The PhD Program in Biomedical Engineering at WPI, hereafter referred to as the WPI PhD Program, and the PhD Program in Biomedical Engineering and Medical Physics offered jointly by WPI and UMMS, hereafter referred to as the Joint PhD Program.

### **3.1. Admission Requirements and the Application Process**

#### **3.1.1. Admission Requirements**

Applicants to either PhD program are expected to have an undergraduate degree and a strong background in engineering and mathematics and to achieve basic and advanced knowledge in engineering, life sciences, and biomedical engineering. For the Joint PhD Program, students are also expected to have had one semester of organic chemistry, a full year of biology, and mathematics through differential equations. Admission normally requires a minimum GPA of 3.2 (out of 4.0) and a minimum quantitative score of 700 on the GRE. The combined verbal and quantitative score should be at least 1200. Special programs are available for outstanding graduates lacking the necessary prerequisites or with a background in the physical or life sciences. These special programs typically involve an individualized plan of course work at the advanced undergraduate level, with formal admittance to the program following the successful completion of this course work.

#### **3.1.2. Application Procedure**

Application to the WPI PhD Program must be made through the GSE at WPI. Application to the Joint PhD Program may be made either through the GSE at WPI or the GSBS Office at UMMS. Details on the application process to either school are given below.

##### **3.1.2.1. Application through WPI**

The GSE Office at WPI (phone: 508-831-5301, email: [gse@wpi.edu](mailto:gse@wpi.edu), <http://www.wpi.edu/Admin/GSE>) accepts both online and paper applications. Online applications are preferred. Requirements for admission include submission of the following:

- A completed *Application for Admission to Graduate Study at WPI*.
- A nonrefundable application fee (waived for WPI alumni).
- Official college transcripts from all accredited degree-granting institutions attended. Admission normally requires a minimum GPA of 3.2 (out of 4.0).

- Three letters of recommendation from individuals who can comment on the qualifications relevant to the applicant's admission. For recently graduated students, a majority of these references should be from faculty.
- Official GRE scores for the General Test (waived for WPI alumni applying to the WPI PhD Program). Admission normally requires a minimum quantitative score of 700 on the GRE. The combined verbal and quantitative score should be at least 1200.
- TOEFL scores must be submitted by all foreign applicants (waived for foreign students presently attending a U.S. school). TOEFL scores are only valid for two years. A minimum score of 550 (600 for Joint PhD Program) on the paper exam or 213 on the computer-based exam is required.
- Statement of Purpose. This is a brief essay discussing background, interests, *academic intent*, and the reasons the applicant feels he/she would benefit from the PhD program in biomedical engineering.

Applicants must observe the application and financial aid deadlines imposed by the GSE. BME Program Faculty from WPI and UMMS (for Joint PhD Program applicants) review complete applications received by the GSE. Incomplete applications are not generally reviewed.

### **3.1.2.2. Application through the University of Massachusetts Medical School (UMMS) for the Joint PhD Program**

Application to the Joint PhD program may be made through the Graduate School of Biomedical Sciences at UMMS (phone: 1-888-860-2334, <http://www.umassmed.edu/gsbbs>). Requirements for admission include submission of the following:

- A completed UMMS *Graduate School of Biomedical Sciences Application for Admission* form.
- A nonrefundable application fee.
- Complete official transcripts for all undergraduate and graduate institutions attended. Admission normally requires a minimum GPA of 3.2 (out of 4.0).
- Three letters of recommendation from individuals who are able to assess your academic performance and prospective success in graduate-level work. For recently graduate students, a majority of these references should be from faculty.
- Official GRE scores for the General Test. Admission normally requires a minimum quantitative score on the Graduate Record Examination of 700. The combined verbal and quantitative score should be at least 1200.
- TOEFL scores must be submitted by all foreign applicants. A minimum score of 600 on the paper examination is required.
- Personal Statement. This is a brief essay discussing background, interests, academic intent, and the reasons the applicant feels he/she would benefit from the WPI/UMMS Joint PhD Program in Biomedical Engineering and Medical Physics.

Applicants must observe the application and financial aid deadlines imposed by the GSBS. BME Program Faculty from WPI and UMMS review complete applications received by the GSBS. Incomplete applications are not generally reviewed.

### **3.1.3. Financial Aid**

Fellowships, research assistantships (RAs), and teaching assistantships (TAs) are available on a competitive basis to outstanding graduate students in both PhD Programs. Fellowships are awarded by WPI, UMMS, national organizations, and corporate sponsors. RAs are awarded to graduate students by individual faculty members. For students in the WPI PhD Program, TAs may be awarded on a competitive basis to support undergraduate teaching in the BME Department at WPI (TAs are not awarded to students in the Joint PhD Program). For students in the WPI PhD Program, a decision on financial aid is made separate from and typically follows the admission decision. For students in the Joint PhD Program, where institutional stipend and tuition support from WPI and UMMS is generally guaranteed for the first two years in the program, a decision on admission and financial aid are made simultaneously. Subsequent years of support for student's in the Joint PhD Program are derived from the student's Research Advisor.

### 3.1.4. Provisional Admission

For outstanding applicants lacking the necessary prerequisites in engineering or with a strong background in the physical or life sciences, provisional admission may be granted to the WPI PhD Program. Students who are admitted provisionally must demonstrate, to the satisfaction of the program, a potential to succeed as a PhD student before formal admittance is granted. For this, the student:

- Must take a sequence of thematically-related undergraduate and/or graduate engineering courses, such that they demonstrate basic competence at a level of the Bachelor's degree in engineering. Grades of "B" or higher are required.
- Must demonstrate a competence in mathematics. This is most often accomplished by successfully completing (with grades of "B" or higher) a sequence of mathematics courses including differential and integral calculus and differential equations.
- Should demonstrate a competence in biology and physiology. This is most often accomplished by successfully completing (with grades of "B" or higher) one course in cell biology and one course in physiology at the undergraduate-level.
- Must demonstrate a knowledge of undergraduate physics. If the student does not have a physics background, course work should include at least General Physics (Mechanics, Electricity and Magnetism, Oscillations and Waves). Grades of "B" or higher are required.

An individualized plan of course work, typically including classes at the advanced undergraduate level, will be developed by the student's Academic Advisory Committee. These courses may be taken at WPI or another approved institution and should be oriented toward engineering students. Provisional students will typically be reviewed and considered for formal admittance into the WPI PhD Program after two semesters of course work.

In addition to the course work requirements detailed above, the following points should also be noted for provisional students:

- The Joint PhD Program does not admit students provisionally.
- Institutional fellowships and awards from WPI, including TAs will not be offered. Other types of awards, such as corporate sponsorship or RAs are still possible.
- Important timelines and completion deadlines in the WPI PhD Program may be delayed. For example, PhD students are required to take the PhD QE no later than the start of the third year. This period of time does not include that time spent as a provisional student in the program.

Remedial course work, which is not acceptable for graduate credit, normally cannot be used to meet the degree requirements for the PhD.

## 3.2. Summary Degree Requirements

Students in either PhD program must simultaneously satisfy the following degree requirements:

- WPI's General Requirements for All Advanced Degrees.
- WPI's General Requirements for the PhD Degree.
- The BME Program's Specific Requirements for the PhD Degree.

The first two institutional degree requirements are summarized below and detailed in the WPI's Graduate Catalog. The BME Program's specific degree requirements are explained fully in this chapter of the Handbook. These program requirements have been structured to incorporate all institutional degree requirements, so that satisfying the BME Program's degree requirements for the PhD will also satisfy the institutional degree requirements. All degree requirements must be satisfied before the degree is awarded.

Students in the Joint PhD Program must also satisfy the Requirements for the PhD Degree of the GSBS at UMMS. The GSBS institutional degree requirements are summarized below and detailed in the Faculty/Student Handbook for the GSBS at UMMS. Again, satisfying the BME Program's degree requirements for the PhD will also satisfy the institutional degree requirements of the GSBS for students in the Joint PhD Program.

### 3.2.1. Institutional Degree Requirements

#### 3.2.1.1. WPI's General Requirements for all Advanced Degrees

All students in either PhD program must satisfy the following:

- At the time the degree is awarded, the student must have been admitted to one of the two PhD programs in Biomedical Engineering.
- A minimum of two-thirds of the required graduate credit for an advanced degree must have been earned at WPI. (Note: Courses in the GSBS may substitute for WPI graduate credit for students in the Joint PhD Program).
- The student must have a program GPA of 3.0 or greater for courses taken at WPI and GSBS.
- The student must satisfy the graduate rules in effect at a specific date between their matriculation date and their graduation date. In applying for graduation (the WPI Graduate Student *Application for Graduation*), the student must specify, by year, which WPI Graduate Catalog contains the rules being satisfied.

After the WPI *Application for Graduation* is submitted, all advanced degrees are subject to the final approval of the Committee on Graduate Studies and Research (CGSR) at WPI, which determines if the student has satisfied the letter of intent of the requirements for the PhD. The CGSR makes its recommendations for the approval of the PhD to the WPI faculty, which in turn recommends to the President and Trustees for their final approval the names of students who should be awarded the doctorate in biomedical engineering.

### **3.2.1.2. WPI's General Requirements for the PhD Degree**

All students in either PhD program must satisfy the following:

- The student must demonstrate to the faculty high academic attainment and the ability to conduct original independent research.
- The student must complete a minimum of 90 credit hours of graduate work beyond the bachelor's degree, or a minimum of 60 credit hours of graduate work beyond the master's degree, including in either case at least 30 credit hours of thesis research.
- The student must establish residency by being a full time graduate student for at least one continuous academic year (Note: The BME Program's Specific Requirements for the PhD Degree requires a full-time effort for a minimum of at least three years, which is longer than that specified by WPI).
- The student must attain status as a PhD candidate by satisfying the BME Program's Specific Requirements for the PhD Degree.
- The student must prepare a PhD dissertation, and defend it before a Dissertation Committee (the PhD Dissertation Examination), at least two of whose members must be from the PhD Program in BME, and at least one of whose members must be from outside the PhD Program in BME. After a successful defense, determined by a majority vote in the affirmative by the Dissertation Committee, the dissertation must be endorsed by those members of the Dissertation Committee who voted to approve it. The completed dissertation must follow in format the instructions published by the WPI library. After final approval for format of the dissertation, the Associate Provost for Academic Affairs will notify the registrar that the dissertation has been approved.
- Once the student has satisfied the BME Program's candidacy requirements (see below), the student will be permitted to enroll for dissertation credits. Prior to the completion of all candidacy requirements, a student may enroll for no more than 18 credits of directed research.

### **3.2.1.3. Requirements for the PhD Degree of the Graduate School of Biomedical Sciences (GSBS) at UMMS**

All students in the Joint PhD program must satisfy the following:

- Pass the core requirements and all graduate courses and laboratory rotations required by the Joint PhD Program (Note: the term "core requirements" does NOT necessarily mean the Biomedical Science Core of the GSBS for Joint PhD Program students).
- Pass the PhD Qualifying Examination.
- Fulfill the teaching requirement.

- Write a PhD Dissertation on the student's original research.
- Pass the final PhD Dissertation Examination.

All advanced degrees are subject to final administrative approval by the Dean of Graduate Studies at UMMS.

### 3.2.2. Summary of the BME Program Requirements for the PhD Degree

While a complete description of the BME Program's requirements for the PhD degree are provided later in this chapter, the following is a summary of these requirements. All students in both PhD Programs must satisfy the following:

- Pass the course requirement, including required laboratory rotations.
- Pass the PhD Qualifying Examination.
- Fulfill the teaching requirement.
- Fulfill the seminar requirement.
- Fulfill the residency requirement.
- Write a PhD Dissertation on the student's original research.
- Pass the final PhD Dissertation Examination.

### 3.2.3. Exceptions and Petitions for Change

Exceptions to general and specific degree requirements or to other rules may be made, but only by written petition to the CGSR at WPI and, for students in the Joint PhD Program, simultaneously to the Dean of the GSBS. A petition to CGSR or the Dean of GSBS should be initiated by the student and may be supported by the BME Program Steering Committee.

## 3.3. Committees and Advising

### 3.3.1. Overview

Various committees and advisors are charged with monitoring and directing the progress of students in the two PhD programs. These committees and advisors are summarized below:

- Academic Advisory Committee – An *ad hoc* committee formed to provide the student with counsel and information during the early years in the Program. This committee advises the student from entry into the Program until: 1) completion of the laboratory rotations; 2) a Research Advisor has been selected; and 3) the student is ready for the PhD Qualifying Examination.
- Qualifying Examination Committee (QEC) – An *ad hoc* committee formed to administer the PhD Qualifying Examination to the student.
- Thesis Research Advisory Committee (TRAC) – An *ad hoc* committee formed to advise the student from the time that the Academic Advisory Committee has formally decided that the student is ready for the PhD Qualifying Examination until the student has submitted the completed dissertation.
- Dissertation Examination Committee – An *ad hoc* committee formed to administer the PhD Dissertation Examination to the student.
- Research Advisor (Dissertation Mentor) – A BME Program Faculty Member charged with mentoring and supporting the dissertation research project.

There are also a number of oversight committees charged with insuring that the PhD Programs are administered consistently. These oversight committees are summarized below:

- BME Graduate Studies Committee – A committee responsible for administering the WPI PhD Program (see Section 2.3.8 for details). References to the BME Steering Committee made elsewhere in this chapter refer to this particular committee for students pursuing the WPI PhD Degree in Biomedical Engineering.
- Joint Program Steering Committee – A committee responsible for administering the Joint PhD Program (see Section 2.3.8 for details). References to the BME Steering Committee made elsewhere in this chapter refer to this committee for students pursuing the WPI/UMMS Joint PhD Degree in Biomedical Engineering and Medical Physics.

In the sections that follow on the various committees, the following definition holds:

- BME Program Faculty Member – a faculty member holding a primary appointment at WPI or the GSBS and formally approved by the BME Steering Committee (see Section 2.3.8 for details). Only a BME Program Faculty Member may serve as Research Advisor (Dissertation Mentor).

### **3.3.2. Standards for All Committees**

The Chair for each committee shall keep records of all meetings and send copies of the records to other committee members and, after their approval, to the BME Steering Committee. The BME Steering Committee shall distribute the records, after checking them for compliance with the rules and regulations, to the student and a copy shall be kept in the student's file(s). Students in the Joint PhD Program have two identical student files, one in the Department of Biomedical Engineering at WPI and the other in the GSBS Graduate Office at UMMS.

### **3.3.3. Academic Advisory Committee**

Each student entering either PhD Program is advised by an Academic Advisory Committee. This committee meets with the student at least twice yearly, normally just before each academic semester.

#### **3.3.3.1. Duties of the Academic Advisory Committee**

- Meet with the incoming PhD student during the orientation period to go over *this* Handbook in detail, making sure that everyone understands his/her responsibilities.
- Provide the student with counsel and information.
- Assist the student in selecting a sequence of coursework and laboratory rotations.
- Advise the student in the selection of a Research Advisor.
- Assess progress and approve alterations in proposed course work and laboratory rotations.
- Provide a written report of the student's status to the BME Steering Committee following each meeting.
- May serve as the evaluating committee for the student's Teaching Requirement.

#### **3.3.3.2. Structure and Formation of the Committee**

The committee shall be appointed by the BME Steering Committee based on the student's background and research interests and shall consist of a Chair and one or two additional members. All members of the committee must be BME Program Faculty. To best advise students in the Joint PhD Program, one member should be from WPI and another member should be from the GSBS.

### **3.3.4. Qualifying Examination Committee**

Upon recommendation by the Academic Advisory Committee and based on the student's background and research interests, a QEC shall be appointed to administer the PhD QE.

#### **3.3.4.1. Duties of the Qualifying Examination Committee**

- Review the academic record of the candidate.
- Advise the student on preparation for the PhD Qualifying Examination.
- Conduct the examination. The student passes the qualifying examination if at least four of the five committee members vote approval.

#### **3.3.4.2. Structure and Formation of the Committee**

At or near the completion of course work and laboratory rotations, the student's Academic Advisory Committee shall recommend to the BME Steering Committee that the student take the PhD Qualifying Examination. The BME Steering Committee shall then appoint a QEC of one Chair and four additional members, taking into account the recommendations of the Academic Advisory Committee. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least two other members shall be BME Program Faculty.
- At least one BME Program Faculty member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI.

- For students in the Joint PhD Program, at least one BME Program Faculty member must hold a primary faculty appointment in the GSBS.
- At least one member shall be a WPI or GSBS faculty member not associated with the BME Program.
- The student's prospective Research Advisor shall not be a member of this committee. He/she may be present at the examination, but shall not participate in the questioning and shall not be present during discussion and vote on the student's performance.

### **3.3.5. Research Advisory Committee**

This committee shall advise the student from the time that the Academic Advisory Committee has decided that the student is ready for the PhD Qualifying Examination until the student has submitted the completed dissertation. The committee shall meet at least once per semester and whenever requested by the chair, the student, or the BME Steering Committee.

#### **3.3.5.1. Duties of the Thesis Research Advisory Committee**

- Serves in an advisory capacity to the student.
- Evaluates and approves a written dissertation proposal presented to it by the student.
- Reviews and advises on research progress.
- Determines when the student is ready to begin writing the dissertation.
- Monitors the progress of writing the dissertation.
- Serves in an advisory capacity to the student and Research Advisor if any conflicts arise between the Research Advisor and the student, in which case the mentor excuses him/herself from the committee proceedings.
- May serve as the evaluating committee for the student's Teaching Requirement.

#### **3.3.5.2. Structure and Formation of the Committee**

The committee shall be appointed by the BME Steering Committee upon the recommendation of the Research Advisor and shall consist of a Chair (usually the Research Advisor) and two or more additional members who can best judge the research. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least two other members shall be BME Program Faculty.
- At least one member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI.
- For students in the Joint PhD Program, at least one member must hold a primary faculty appointment in the GSBS.

### **3.3.6. Dissertation Examination Committee**

Upon recommendation by the Research Advisory Committee, a Dissertation Examination Committee shall be formed to administer the PhD Dissertation Examination.

#### **3.3.6.1. Duties of the PhD Dissertation Examination Committee**

- Conduct the examination. The student passes the dissertation examination if a majority of the committee members vote approval. After a successful defense, those members who voted to approve it must endorse the dissertation.

#### **3.3.6.2. Structure and Formation of the Committee**

The student's Research Advisory Committee shall recommend to the BME Steering Committee that the student take the PhD Dissertation Examination. The BME Steering Committee shall then appoint a Dissertation Examination Committee of a Chair and at least four additional members, taking into account

the recommendations of the Research Advisory Committee and the Research Advisor. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least two other members shall be BME Program Faculty.
- At least one BME Program Faculty member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI.
- For students in the Joint PhD Program, at least one BME Program Faculty member must hold a primary faculty appointment in the GSBS.
- At least one member shall be a WPI or GSBS faculty member not associated with the BME Program.
- At least one member shall be from an institution other than WPI or UMMS. This member normally attends the examination; in unusual circumstances, the outside examiner will be exempt from attending but shall then submit a written report on the dissertation.

### **3.3.6.3. Rules and Responsibilities for the PhD Dissertation Examination**

- The Chair sets the date of the examination and oversees the examination and all meetings of the committee.
- Committee members shall receive a copy of the Dissertation after the Research Advisor has approved it. This copy must be essentially in its final form, pending any changes required by the committee.
- Committee members must receive the dissertation at least 14 days before the date of the scheduled examination.
- Committee members must report to the Chair at least 48 hours before the examination if they find the dissertation to be in an inadequate form to proceed with the oral dissertation examination.
- The Chair reports at least 24 hours before the examination to the other committee members, the student, and the BME Steering Committee if a committee member finds the dissertation to be in an inadequate form to proceed with the oral dissertation examination.
- Committee members approve and sign the final copy of the dissertation. The Chair designates one committee member to supervise that any alterations of the dissertation be completed before submission to the BME Steering Committee. He/she shall not sign the Dissertation until all of these corrections/alterations are completed.
- The Chair reports in writing to the BME Steering Committee the results of the examination and the decision of the committee.
- The Dean of the GSBS at UMMS must administratively approve all dissertations for students in the Joint PhD Program.

### **3.3.7. Research Advisor (Dissertation Mentor)**

The student selects a Research Advisor (or Dissertation Mentor) upon completion of all laboratory rotations. The Research Advisor must be an approved BME Program Faculty Member and must agree to mentor the student.

#### **3.3.7.1. Duties of the Research Advisor**

- Must demonstrate a reasonable ability to provide adequate financial support for conducting the research project and supporting the student.

### **3.3.8. BME Steering Committee**

The BME Steering Committee is responsible for administering the PhD Programs in BME. It acts as a liaison between the faculty and students in the program and the administrative structures at WPI and the GSBS (for Joint PhD students). The make-up of this committee is different for the two PhD Programs:

- For students in the WPI PhD Program, the BME Graduate Studies Committee serves as the BME Steering Committee.
- For students in the Joint PhD Program, the Joint Program Steering Committee serves as the BME Steering Committee.

### 3.3.8.1 Duties of the BME Steering Committee

- Oversees and administers the PhD Program.
- Appoints WPI and GSBS faculty as BME Program Faculty Members.
- Appoints BME Program Faculty Members to a student's Academic Advisory Committee based on the student's background and research interests.
- Appoints faculty to a student's QEC based on the student's background and research interests and the recommendations of the student's Academic Advisory Committee
- Based upon the recommendations of the student's Research Advisor, appoints faculty to a student's Research Advisory Committee
- Based upon the recommendations of the Research Advisory Committee, appoints faculty to a student's Dissertation Examination Committee.
- Appoints BME Program Faculty Members to different sub-committees, including the Admissions Committee.
- Monitors the progress of students in the PhD Program.
- Acts on admission of students in the PhD Program to degree candidacy.
- Acts on student and faculty petitions on academic matters.

### 3.4. Course Requirement

The PhD program has no formal course requirements. However, because research in the field of biomedical engineering requires a solid working knowledge of a broad range of subjects in the life sciences, engineering, and mathematics, course credits must be distributed across the following categories with the noted minimums:

- Biomedical Engineering (12 credits)
- Life Sciences (9 credits)
- Advanced Engineering Mathematics (6 credits)
- Laboratory Rotations (6 credits)
- Responsible Conduct of Science (1 credit)
- Advanced Courses and Electives (12 credits)
- Dissertation Research (30 credits)

The student's Academic Advisory Committee may require additional course work to address specific deficiencies in the student's background. Up to 9 credits at the advanced undergraduate level (4000-level) may be used to satisfy these course requirements. Note that graduate life science courses in the BME Department at WPI (BE 560 and BE 562) can not be used to satisfy the life science requirement for students in the Joint PhD Program.

#### 3.4.1. Standards for Course Grades

- Students must maintain a GPA of at least 3.0 on a scale of 4.0, where A = 4.0, B = 3.0, C = 2.0, D = 1.0, and F = 0.0. A grade of Pass does not count toward the GPA.
- Students may have a C grade in at most two courses for credit to count towards the PhD; no D or F grades are allowed.

#### 3.4.2. Seminar Requirement

The PhD Program requires that all students attend weekly seminars and, in addition, present a seminar once a year. To facilitate this process, students must enroll in the class *BE 591 – Graduate Seminar*. All PhD students are required to pass BE 591 four times. This graduate course is graded pass/fail for zero credits.

#### 3.4.3. Typical Curriculum

The following are representative examples of course work for different specializations in the PhD Program.

#### **3.4.3.1. Bioinstrumentation/Biosensor Specialization**

#### **3.4.3.2. Biomechanics/Biomaterials Specialization**

#### **3.4.3.3. Biomedical Imaging Specialization**

#### **3.4.3.4. Tissue Engineering**

### **3.5. Laboratory Rotations**

Students are required to participate in at least two different laboratory rotations during their first two years in the PhD Program. Laboratory rotations – short periods of research experience under the direction of WPI or GSBS faculty members – are intended to familiarize students with concepts and techniques in several different engineering and scientific fields. They allow faculty members to observe and evaluate the research aptitudes of students and permit students to evaluate the types of projects that might be developed into dissertation projects. Upon completion of each rotation, the student submits a written report on the research accomplished. Each rotation is a three- or four-credit course and lasts a minimum of eight weeks if the student participates full time in the laboratory or up to a full semester if the student takes courses at the same time.

#### **3.5.1. Standards for Laboratory Rotations**

- The choice of rotations is made in consultation with and approved by the student's Academic Advisory Committee.
- Rotations shall be taken only with WPI or GSBS faculty members (Note: Dissertation projects can only be taken with approved BME Program Faculty and not all WPI or GSBS faculty members are BME Program Faculty).
- A rotation should be considered equivalent to a course with a similar commitment of both student and faculty.
- All rotations begin on the first day of class; either fall, spring, or summer semester. During the first 18 months in the Program, two full-semester rotations must be taken. Double rotations (two one-half rotations per semester) may be taken as long as the two full-semester rotation requirement is fulfilled.
- The student will prepare a written report on his or her rotation. The report should be a 1-2 page (maximum) summary of the project and the research experience. Primary data, figures, tables, etc. are not required or expected. A report is required for all rotations, regardless of length. The report should be submitted to the Principal Investigator (PI) and to the BME Steering Committee within 2-3 weeks after completion of the rotation. The research summary should be reviewed by the PI for the benefit of the student. However, formal evaluation of the research summary by the PI is not expected. The research summary is to become part of the student's permanent record. Students will not be permitted to take the qualifying examination unless all research summaries are present in the permanent record(s) at WPI (and the GSBS).
- Students will be given 3 credits for full fall or spring rotations (double one-half rotations will receive 1.5 credits each). The rotation is expected to occupy a minimum of 12 hours per week during the academic year. The student will be given 4 hours credit for the full summer rotation (or 2 credits each for double one-half rotations). Students should take no more than 9 other credits simultaneously with a rotation during the fall and spring semesters. Students may take additional rotation periods in the same laboratory, but must rotate through 2 different labs to satisfy the rotation requirement.
- Faculty members must provide to the students an explanation of the rotation projects, its goals, and an estimation of the time commitment.
- The student shall receive a letter grade (A,B,C,D or F) for the rotation. Faculty members may provide a written evaluation of the student at the end of the rotation – to be made available to the student. The student will have an opportunity to discuss this evaluation with the faculty member before it is sent to the BME Steering Committee. The student may choose to provide an accompanying evaluation of his or her laboratory experience with the faculty member's evaluation.

### **3.6. PhD Qualifying Examination**

Students are required to pass a PhD QE no later than the start of the third year after formal admittance to the PhD program. This examination is a defense of an original research proposal, outside the area of the student's prospective dissertation topic, made before a committee representative of the area of specialization. The examination is used to evaluate the ability of the student to pose meaningful engineering and scientific questions, formulate scientific hypotheses, to propose experimental methods for answering those questions, and to interpret the validity and significance of probable outcomes of these experiments. It is also used to test a student's comprehension and understanding of their formal course work in the life sciences, biomedical engineering, and mathematics.

#### **3.6.1. Standards for the PhD Qualifying Examination**

- The administration of a PhD QE constitutes acceptance of the student by the Program, which implies the availability and willingness of one or more Research Advisors.
- All PhD students must pass their QE before the start of their third year of formal course work or they will be subject to dismissal from the Program.
- A student passes the PhD QE if at least four of the five members of the QEC vote approval. If a student fails the examination, only extraordinary circumstances will dictate the administration of a second examination. Only one repeated examination may be held upon the request of the PhD QEC and with the concurrence of the BME Steering Committee.
- If a student fails to pass the examination on the second attempt and does not have a master's degree in biomedical engineering from WPI, the QEC has the option of allowing the student to attempt a Master of Science (MS) in BME or meet the Master of Engineering (ME) degree requirements. If the student meets the requirements for the MS or ME degree, it will be granted as a terminal degree.

#### **3.6.2. Format and Timetable of the Examination**

- The QE shall be of the research proposal type. The student shall choose one or more research problems not related to his/her dissertation research and first prepare a one-paragraph abstract describing an experimental approach to each problem for review by the members of the QEC.
- With the approval of the QEC, the student shall then prepare a written research proposal on the problem approved by the committee. The proposal should be in NIH grant format and should include a review of the relevant literature, a clear statement of the problem, a research plan, and justification of the research plan. It should also include all proposed experiments, along with interpretations of probable outcomes of the experiments described.
- The written research proposal shall be given to the QEC at least 10 days before the examination, at which time the student will present and defend this proposal. The student will first present a 30 – 50 minute public seminar on the proposal and then defend it before the PhD QEC. The Committee may ask questions on any subject with which the student should be familiar, whether or not it is related to the research proposal(s). This includes all course work that the student has taken while in the PhD program. The committee then decides whether the student has sufficient ability and preparation to undertake independent research leading to a PhD degree.
- The BME Departmental Office at WPI and the GSBS Graduate Office at UMMS (for students in the Joint PhD Program) shall appropriately publicize the PhD QE public seminar at least 7 days prior to the examination date.

### **3.7. Admission to Candidacy**

Formal admission to candidacy in the PhD Program is conferred upon students who have completed their core course work (exclusive of thesis research) and laboratory rotation and passed the PhD Qualifying Examination. With candidacy, the student will be permitted to enroll for dissertation credits. Prior to completion of the candidacy requirements, a student may enroll for no more than 18 credits of directed research (BE 598).

### **3.8. PhD Dissertation Proposal**

The PhD Dissertation Proposal is a written document prepared and defended before the student's Research Advisory Committee. Formal acceptance of student's dissertation research program follows the approval of this proposal. The proposal should not be thought of as an examination. Rather, it serves two very important functions:

- An accepted proposal provides a guarantee to the student that the Research Advisory Committee found the proposed research program acceptable.
- It provides the student with important feedback on his/her proposed research. Although the Research Advisor will certainly provide the student with the most valuable advice, the Research Advisory Committee can also provide additional insights and feedback.

#### **3.8.1. Standards for the PhD Dissertation Proposal**

- The proposal should be presented within one calendar year of taking the PhD QE or as soon as a line of research has been defined and there is evidence that the experimental protocols can be carried out.
- The proposal must be formally approved by the Research Advisory Committee before the student can formally begin writing the actual PhD Dissertation Document.
- The proposal is approved if a majority of the Research Advisory Committee members vote approval. Generally, most proposals are approved. If the line of research proposed is too distant from what the Research Advisory Committee considers "Biomedical Engineering" or, more often, if the hypotheses to be tested are not stated clearly enough, the student will be asked to resubmit the proposal.

#### **3.8.2. Format and Timetable for the Proposal**

- The written proposal should be in the form of an NIH grant request and should be cast in the form of hypothesis-testing, not fact gathering. The proposal should include the Specific Aims, Background and Significance, Preliminary Results, and Methods. It need not include the Budget.
- The student presents the proposal orally at a scheduled Research Advisory Committee meeting. The written PhD Dissertation Proposal shall be given to the Research Advisory Committee at least 10 days before this meeting. The student will be expected to speak for no longer than 30 minutes and the Committee will probably spend about 30 minutes asking questions. The committee then decides in a closed session whether the student has successfully defended his/her proposal.

### **3.9. PhD Dissertation Document and Defense**

All PhD students must prepare a dissertation document and defend it before a Dissertation Examination Committee. For this requirement, PhD program students must:

- Present a one-hour public seminar (PhD Dissertation Seminar or Oral Defense) on the results of the completed dissertation project.
- On the same day, successfully pass the PhD Dissertation Examination.
- Present an acceptable and appropriately signed dissertation to the BME Steering Committee. Administrative approval by this committee constitutes acceptance of the dissertation.
- For students in the Joint PhD Program, present an acceptable and appropriately signed dissertation to the Dean of the GSBS at UMMS for administrative approval. The approval of the BME Steering Committee is required before submission to the Dean.

#### **3.9.1. PhD Dissertation Seminar (Oral Defense)**

The BME Departmental Office at WPI and the GSBS Graduate Office at UMMS (for students in the Joint PhD Program) shall appropriately publicize the dissertation seminar at least 14 days prior to the examination date. The seminar shall be of the standard research seminar format and shall be limited to approximately one hour; it forms an integral part of the examination.

#### **3.9.2. PhD Dissertation Examination**

Following the PhD Dissertation Seminar, the student must defend the dissertation before the Dissertation Examination Committee. The student successfully passes the examination if a majority of the committee members vote approval. If the student does not pass the examination, the Committee shall make a recommendation to the BME Steering Committee. This recommendation may include:

- Rewriting the dissertation or part of it.
- Doing additional experimental or theoretical work on the dissertation subject.
- Studying background material pertaining to the field of specialization.
- Presenting another seminar.
- Being awarded a Master of Science (MS) degree or Master of Engineering (ME) degree from WPI for coursework and research completed.

### **3.9.3. PhD Dissertation Document**

A copy of the dissertation, which must be given to all Dissertation Examination Committee members, shall:

- Be a finished product and approved by the Research Advisor.
- Conform to the dissertation standards of WPI and the University of Massachusetts (for students in the Joint PhD Program).

The dissertation must contain:

- A concise, but comprehensive, *Introduction*.
- A concise, but comprehensive, *Discussion* relating the results presented to the current and future state of the field.
- Intervening pages consisting of either: (i) *Materials and Methods*, and *Results* section or, (ii) the text of a series of articles in manuscript form published in or ready to be submitted to peer-review Journals with the candidate as first author. Work conducted by someone other than the student must be clearly identified and referenced as such in the dissertation.
- A comprehensive *Bibliography*.
- An *Abstract*.
- Figures of a quality suitable for publication.

After successful completion of the PhD Dissertation Examination, the PhD dissertation document shall be:

- Revised and corrected according to the decisions of the examination committee.
- Signed by all committee members who voted approval of the document and the Research Advisor.
- Submitted to the BME Steering Committee for administrative approval.
- Submitted to the Dean of the GSBS at UMMS for administrative approval (for students in the Joint PhD Program only).
- Submitted in a format suitable for archiving and storage. Students must follow the regulations for preparation of dissertations published by the library at WPI. For students in the Joint PhD Program, the regulations of the GSBS library must also be followed.

Please note that PhD students must be registered at WPI for 3 semester credit hours in the semester that the degree requirements are completed.

### **3.10 Teaching Requirement**

All candidates for the PhD degree must demonstrate teaching skills by preparing, presenting, and evaluating a teaching exercise. This experience may involve a research seminar, lecture, demonstration, or conference in the context of a medical school basic science course or BME course at WPI. Formal parts of the presentation may be videotaped as appropriate. The presentation and associated materials are critiqued and evaluated by program faculty members. The student's academic advisory committee is responsible for evaluating the teaching exercise based on criteria previously defined. The teaching requirement can be fulfilled at any time and there is no limit to the number of attempts a student may make to fulfill this requirement. It must, however, be completed successfully before the dissertation defense can be held.

### **3.11. Residency Requirement**

The PhD program requires a full-time effort for a minimum of at least 3 years. An explicit and detailed definition of “full-time” status is given in the WPI Graduate Catalog.

### **3.12. Combined Master’s of Engineering (ME) / PhD Degree**

Most PhD students that do not start with a master’s degree in biomedical engineering will, within 2-3 years of study, satisfy all the requirements for the Master’s of Engineering (ME) degree in BME. Upon written request to the BME Steering Committee, students who qualify will be awarded a ME degree in recognition of their achievements. Earning this degree will not change any of the PhD requirements. Students should note that PhD dissertation credits do not count towards this degree. The required credits for the ME degree may be based on directed research credits (BE 598).

## **4. Master’s of Science (MS) Degree Program**

This chapter describes the BME MS Degree Program in detail.

### **4.1. Admission Requirements and the Application Process**

#### **4.1.1. Admission Requirements**

Applicants to the MS Degree Program are expected to have an undergraduate degree and a strong background in engineering and mathematics and to achieve basic and advanced knowledge in engineering, life sciences, and biomedical engineering. Admission normally requires a minimum GPA of 3.2 (out of 4.0) and a minimum quantitative score of 700 on the GRE. The combined verbal and quantitative score should be at least 1200. Special programs are available for outstanding graduates lacking the necessary prerequisites or with a background in the physical or life sciences. These special programs typically involve an individualized plan of course work at the advanced undergraduate level, with formal admittance to the program following the successful completion of this course work.

#### **4.1.2. Application Procedure**

Application must be made through the GSE at WPI. The GSE at WPI (phone: 508-831-5301, email: [gse@wpi.edu](mailto:gse@wpi.edu), <http://www.wpi.edu/Admin/GSE>) accepts both online and paper applications. Online applications are preferred. Requirements for admission include submission of the following:

- A completed *Application for Admission to Graduate Study at WPI*.
- A nonrefundable application fee (waived for WPI alumni)
- Official college transcripts from all accredited degree-granting institutions attended. Admission normally requires a minimum GPA of 3.2 (out of 4.0).
- Three letters of recommendation (and/or other references) from individuals who can comment on the qualifications relevant to the applicant’s admission.
- Official GRE scores for the General Test (waived for WPI alumni). Admission normally requires a minimum quantitative score of 700 on the GRE. The combined verbal and quantitative score should be at least 1200.
- TOEFL scores must be submitted by all foreign applicants (waived for foreign students presently attending a U.S. school). TOEFL scores are only valid for two years. A minimum score of 550 on the paper exam or 213 on the computer-based exam is required.
- Statement of Purpose. This is a brief essay discussing background, interests, academic intent, and the reasons the applicant feels he/she would benefit from the MS program in biomedical engineering.

Applicants must observe the application and financial aid deadlines imposed by the GSE. The BME Admissions Committee reviews complete applications received by the GSE. Incomplete applications are not generally reviewed.

#### **4.1.3. Financial Aid**

Fellowships, research assistantships (RAs), and teaching assistantships (TAs) are available on a competitive basis to outstanding graduate students in the MS Program. Fellowships are awarded by WPI, national organizations, and corporate sponsors. RAs are awarded to graduate students by individual faculty members. TAs are awarded on a competitive basis to support undergraduate teaching in the BME

Department at WPI. A decision on financial aid is made separate from and typically follows the admission decision.

#### **4.1.4. Provisional Admission**

For outstanding applicants lacking the necessary prerequisites in engineering or with a strong background in the physical or life sciences, provisional admission may be granted to the MS Program. Students who are admitted provisionally must demonstrate, to the satisfaction of the program, a potential to succeed as an MS student before formal admittance is granted. For this, the student:

- Must take a sequence of thematically-related undergraduate and/or graduate engineering courses, such that they demonstrate basic competence at a level of the Bachelor's degree in engineering. Grades of "B" or higher are required.
- Must demonstrate a competence in mathematics. This is most often accomplished by successfully completing (with grades of "B" or higher) a sequence of mathematics courses including differential and integral calculus and differential equations.
- Must demonstrate a knowledge of undergraduate physics. If the student does not have a physics background, course work should include at least General Physics (Mechanics, Electricity and Magnetism, Oscillations and Waves). Grades of "B" or higher are required.

An individualized plan of course work, typically including classes at the advanced undergraduate level, will be developed by the student's Academic Advisor. These courses may be taken at WPI or another approved institution and should be oriented toward engineering students. Provisional students will typically be reviewed and considered for formal admittance into the MS Program after two semesters of course work.

In addition to the course work requirements detailed above, the following points should also be noted for provisional students:

- Institutional fellowships and awards from WPI, including TAs will not be offered. Other types of awards, such as corporate sponsorship or RAs are still possible.
- Important timelines and completion deadlines in the program may be delayed.
- Remedial course work, which is not acceptable for graduate credit, normally cannot be used to meet the degree requirements for the MS degree.

## **4.2. Summary Degree Requirements**

Students in the MS program must simultaneously satisfy the following degree requirements:

- WPI's General Requirements for All Advanced Degrees.
- WPI's General Requirements for the Master of Science and Master of Engineering Degrees.
- The BME Program's Specific Requirements for the Master of Science Degree.

The first two institutional degree requirements are summarized below and detailed in the WPI's Graduate Catalog. The BME Program's specific degree requirements are explained fully in this chapter of the Handbook. These program requirements have been structured to incorporate all institutional degree requirements, so that satisfying the BME Program's degree requirements for the MS will also satisfy the institutional degree requirements. All degree requirements must be satisfied before the degree is awarded.

### **4.2.1. Institutional Degree Requirements**

#### **4.2.1.1. WPI's General Requirements for all Advanced Degrees**

All students in the MS program must satisfy the following:

- At the time the degree is awarded, the student must have been admitted to the MS program in Biomedical Engineering.
- A minimum of two-thirds of the required graduate credit for an advanced degree must have been earned at WPI.
- The student must have a program GPA of 3.0 or greater.
- The student must satisfy the graduate rules in effect at a single date between their matriculation date and their graduation date. In applying for graduation (the WPI Graduate Student *Application*

for Graduation), the student must specify, by year, which WPI Graduate Catalog contains the rules being satisfied.

After the *Application for Graduation* is submitted, all advanced degrees are subject to the final approval of the Committee on Graduate Studies and Research (CGSR), which determines if the student has satisfied the letter of intent of the requirements for the MS Degree. The CGSR makes its recommendations for the approval of the MS to the WPI faculty, which in turn recommends to the President and Trustees for their final approval the names of students who should be awarded the Master of Science Degree in Biomedical Engineering.

#### **4.2.1.2. WPI's General Requirements for the Master of Science and Master of Engineering Degrees**

All students in the MS program must satisfy the following:

- The student must obtain a minimum of 30 credit hours of acceptable course, thesis, or project work. At least 6 credit hours must be thesis research.
- The student must obtain a minimum of 21 credit hours of graduate-level courses or thesis (18 credit hours for students in the Combined BS/Master's Program), including at least 15 credit hours of graduate-level courses or thesis in BME. Other courses (to make up the minimum total of 30 credit hours) may include advanced undergraduate courses approved by the BME Graduate Studies Committee. Such courses are normally considered to be at the 4000-level. The BME Graduate Studies Committee must approve the use of advanced undergraduate courses for the satisfaction of MS degree requirements. A 1/3 unit WPI undergraduate course taken for graduate credit is assigned 3 credit hours of graduate credit. A graduate student registered for graduate credit in an undergraduate course may be assigned additional work at the discretion of the instructor.
- The student must prepare a MS thesis document and defend it before a Thesis Committee (the MS Thesis Examination).

#### **4.2.2. Summary of the BME Program Requirements for the MS Degree**

While a complete description of the BME Program's Requirements for the MS Degree are provided later in this chapter, the following is a summary of these requirements. All students must satisfy the following:

- Pass the course requirement.
- Fulfill the seminar requirement (for full-time students).
- Write a MS Thesis on the student's original research.
- Pass the final MS Thesis Examination.

#### **4.2.3. Exceptions and Petitions for Change**

Exceptions to general and specific degree requirements or to other rules may be made, but only by written petition to the Committee on Graduate Studies and Research (CGSR) at WPI. A petition to CGSR should be initiated by the student, but normally should be written on behalf of the student by the BME Graduate Studies Committee.

### **4.3. Committees and Advising**

#### **4.3.1. Overview**

Various advisors and committees are charged with monitoring and directing the progress of students in the MS program. These advisors and committees are summarized below:

- Academic Advisor – A core BME faculty member at WPI designated to provide the student with counsel and information during the early years in the Program. He/She advises the student from entry into the Program until a Research Advisor has been selected.
- Research Advisor (Thesis Mentor) – A BME Program Faculty Member charged with mentoring and supporting the thesis research project.
- Thesis Advisory/Examination Committee – An *ad hoc* committee formed to advise the student after a Research Advisor has been selected and to administer the MS Thesis Examination to the student.

- BME Graduate Studies Committee – A committee responsible for administering the MS Program.

In the sections that follow on the various advisors and committees, the following definitions hold:

- BME Program Faculty Member – a faculty member holding a primary appointment at WPI or the Graduate School of Biomedical Sciences (GSBS) at UMMS and formally approved by the BME Graduate Studies Committee. Only a BME Program Faculty Member may serve as Research Advisor (Thesis Mentor).

#### **4.3.2. Standards for All Advisors and Committees**

Advisors and the Chair for the Thesis Advisory/Examination Committee shall keep records of all meetings with the student and send copies of these records to the BME Graduate Studies Committee. The BME Graduate Studies Committee shall distribute the records, after checking them for compliance with the rules and regulations, to the student and a copy shall be kept in the student's file in the Department of Biomedical Engineering at WPI.

#### **4.3.3. Academic Advisor**

Each student entering the MS Program is advised by an Academic Advisor. This advisor meets with the student at least twice yearly, normally just before each academic semester.

##### **4.3.3.1. Duties of the Academic Advisor**

- Meet with the incoming MS student during the orientation period to go over *this* Handbook in detail, making sure that everyone understands his/her responsibilities.
- Provide the student with counsel and information.
- Assist the student in selecting a sequence of coursework.
- Advise the student in the selection of a Research Advisor.
- Assess progress and approve alterations in proposed course work.
- Provide a written report of the student's status to the BME Graduate Studies Committee following each meeting. The BME Graduate Studies Committee shall distribute the records, after checking them for compliance with the rules and regulations, to the student and a copy shall be kept in the student's file in the Department of Biomedical Engineering at WPI.

##### **4.3.3.2. Selection of the Academic Advisor**

The BME Graduate Studies Committee shall appoint the Academic Advisor. This selection shall be based on common research interests and a potential for that individual to become the student's Research Advisor. The Academic Advisor must be a core BME Faculty Member at WPI. The student may, at any later time, request a new Academic Advisor.

#### **4.3.4. Research Advisor (Thesis Mentor)**

The student selects a Research Advisor (or Thesis Mentor) no later than the end of the second semester, and preferably before the end of the first semester, in the MS Program. The Research Advisor must be an approved BME Program Faculty Member and must agree to mentor the student.

##### **4.3.4.1. Duties of the Research Advisor**

- Must demonstrate a reasonable ability to provide adequate financial support for conducting the research project.

#### **4.3.5. Thesis Advisory/Examination Committee**

This committee shall advise the student after a Research Advisor has been selected and, as a terminal act, administer the MS Thesis Examination. The committee shall meet with the student at least once per semester and whenever requested by the chair, the student, or the BME Graduate Studies Committee.

##### **4.3.5.1. Duties of the Thesis Advisory/Examination Committee**

- Serves in an advisory capacity to the student prior to the MS Thesis Examination.
- Evaluates and approves a written thesis proposal presented to it by the student.
- Reviews and advises on research progress.
- Determines when the student is ready to begin writing the thesis.

- Monitors the progress of writing the thesis.
- Serves in an advisory capacity to the student and Research Advisor if any conflicts arise between the Research Advisor and the student, in which case the mentor excuses him/herself from the committee proceedings.
- Conduct the MS Thesis Examination. The student passes the thesis examination if a majority of the committee members vote approval.

#### **4.3.5.2. Structure and Formation of the Thesis Advisory/Examination Committee**

The committee shall be appointed by the BME Graduate Studies Committee upon the recommendations of the Research Advisor and the student and shall consist of a Chair (usually the Research Advisor) and two or more additional members who can best judge the research. It shall be formed no later than six months following the approval of the Research Advisor. The composition of this committee shall meet the following minimum criteria:

- The Chair and at least one other member shall be BME Program Faculty.
- At least one member must hold a primary faculty appointment in the Department of Biomedical Engineering at WPI (a core BME Faculty Member).

#### **4.3.5.3. Rules and Responsibilities for the MS Thesis Examination**

- The Chair sets the date of the examination and oversees the examination and all meetings of the committee.
- Committee members shall receive a copy of the thesis after the Research Advisor has approved it. This copy must be essentially in its final form and signed by the Research Advisor.
- Committee members must receive the thesis at least 14 days before the date of the scheduled examination.
- Committee members must report to the Chair at least 48 hours before the examination if they find the thesis to be in an inadequate form to proceed with the oral thesis examination.
- The Chair reports at least 24 hours before the examination to the other committee members, the student, and the BME Graduate Studies Committee if a committee member finds the thesis to be in an inadequate form to proceed with the oral thesis examination.
- Committee members approve and sign the final copy of the thesis. The Chair designates one committee member to supervise that any alterations of the thesis be completed before submission to the BME Graduate Studies Committee. He/She shall not sign the thesis until all of these corrections/alterations are completed.
- The Chair reports in writing to the BME Graduate Studies Committee the results of the examination and the decision of the committee.

#### **4.3.6. BME Graduate Studies Committee**

The BME Graduate Studies Committee is responsible for administering the MS Program in BME. It acts as a liaison between the faculty and students in the program and the administrative structures at WPI.

##### **4.3.6.1. Duties of the BME Graduate Studies Committee**

- Oversees and administers the MS Program.
- Appoints WPI and GSBS faculty as BME Program Faculty Members.
- Appoints Academic Advisors for new MS students. An Academic Advisor must be a core BME Faculty Member at WPI.
- Based upon the recommendations of the student's Research Advisor, appoints faculty to a student's Thesis Advisory/Examination Committee.
- Appoints BME Program Faculty Members to different sub-committees, including the Admissions Committee.
- Monitors the progress of students in the MS Program.
- Acts on student and faculty petitions on academic matters.

#### **4.4. Course Requirement**

The MS program has no formal course requirements. Course credits in the MS Program must be distributed across the following categories with the noted minimums:

- Biomedical Engineering (6 credits)
- Life Sciences (6 credits)
- Advanced Engineering Mathematics (6 credits)
- Advanced Courses and Electives (6 credits)
- Thesis Research (6 credits)

Any WPI graduate-level engineering, physics, math, BME, or equivalent course, subject to the approval of the BME Graduate Studies Committee, may be used for Advanced Courses and Electives. The student must obtain a minimum of 21 credit hours of graduate-level courses or thesis (18 credit hours for students in the Combined BS/Master's Program), including at least 15 credit hours of graduate-level courses or thesis in BME. Other courses (to make up the minimum total of 30 credit hours) may include advanced undergraduate courses approved by the BME Graduate Studies Committee. Such courses are normally considered to be at the 4000-level. The BME Graduate Studies Committee must approve the use of advanced undergraduate courses for the satisfaction of MS degree requirements and the student's Academic Advisor or Thesis Advisory Committee may require additional course work to address specific deficiencies in the student's background.

##### **4.4.1. Standards for Course Grades**

- Students must maintain a GPA of at least 3.0 on a scale of 4.0, where A = 4.0, B = 3.0, C = 2.0, D = 1.0, and F = 0.0. A grade of Pass does not count toward the GPA.
- Students may have a C grade in at most two courses for credit to count towards the MS Degree; no D or F grades are allowed.

##### **4.4.2. Seminar Requirement**

The MS Program requires that all students in residence attend weekly seminars and, in addition, present a seminar once a year. To facilitate this process, students must enroll in *BE 591 – Graduate Seminar*. All MS students are required to pass BE 591 twice. This graduate course is graded pass/fail for zero credits.

##### **4.4.3. Typical Curriculum**

The following are representative examples of course work for different specializations in the MS Program.

###### **4.4.3.1 Bioinstrumentation/Biosensor Specialization**

###### **4.4.3.2 Biomechanics/Biomaterials Specialization**

###### **4.4.3.3 Biomedical Imaging Specialization**

###### **4.4.3.4 Tissue Engineering**

#### **4.5. MS Thesis Proposal**

The MS Thesis Proposal is a written document prepared and submitted to the student's Thesis Advisory Committee. Formal acceptance of student's thesis research program follows the approval of this proposal. An accepted proposal provides reasonable assurance that, when the proposed work is completed and written up, it will be accepted as a thesis.

##### **4.5.1. Standards for the MS Thesis Proposal**

- The proposal should be submitted to the Thesis Advisory Committee no later than six months after selecting a Research Advisor or as soon as a line of research has been defined and there is evidence that the experimental protocols can be carried out.
- The Thesis Advisory Committee must formally approve the proposal before the student can formally begin writing the actual MS Thesis Document.
- The proposal is approved if a majority of the Thesis Advisory Committee members vote approval. Generally, most proposals are approved. If the line of research proposed is too distant from what the Thesis Advisory Committee considers "Biomedical Engineering" or, more often, if the

hypotheses to be tested are not stated clearly enough, the student will be asked to resubmit the proposal.

#### **4.5.2. Format of the Proposal**

The formal written proposal shall be prepared by the student and submitted to the Thesis Advisory Committee. It should describe the research to be undertaken and will typically contain the following sections:

- **Introduction** – Statement of the problem, why it is important, what is the proposed approach, why is it potentially better than alternative approaches.
- **Literature Review** – A substantive review of the relevant literature; this does not have to be exhaustive, but should be of sufficient depth to convince the reader that the student is aware of other work in the proposed area of study and to provide a working background of information for the implementation of the proposed work.
- **Proposed Approach** – How is the problem to be attacked? What are the expected problem areas together with their expected, relative difficulties? This section may be speculative but should indicate that the student has considered the problem in depth.
- **Required Facilities** – Laboratory space and equipment, availability of thesis for the duration of the project.

While there is no prescribed length, the proposal should contain sufficient detail and clarity to allow its review by individuals not familiar with the area of study. The student's Thesis Advisory Committee must accept the proposal before substantial work begins on the research.

#### **4.6. MS Thesis Document and Defense**

All MS students must prepare a thesis document and defend it before a Thesis Examination Committee. For this requirement, MS program students must:

- Present a one-hour public seminar (MS Thesis Seminar or Oral Defense) on the results of the completed thesis project.
- On the same day, successfully pass the MS Thesis Examination.
- Present an acceptable and appropriately signed thesis to the BME Graduate Studies Committee. Administrative approval by this committee constitutes acceptance of the thesis.

##### **4.6.1. MS Thesis Seminar (Oral Defense)**

The BME Departmental Office at WPI shall appropriately publicize the thesis seminar at least 14 days prior to the examination date. The seminar shall be of the standard research seminar format and shall be limited to approximately one hour; it forms an integral part of the examination.

##### **4.6.2. MS Thesis Examination**

Following the MS Thesis Seminar, the student must defend the thesis before the Thesis Examination Committee. The student successfully passes the examination if a majority of the committee members vote approval. If the student does not pass the examination, the Committee shall make a recommendation to the BME Graduate Studies Committee. This recommendation may include:

- Rewriting the thesis or part of it.
- Doing additional experimental or theoretical work on the thesis subject.
- Studying background material pertaining to the field of specialization.
- Presenting another seminar.
- Being awarded a Master of Engineering (ME) Degree for coursework and research completed. MS Thesis credits (BE 599) will have to be converted to directed research credits (BE 598).

##### **4.6.3. MS Thesis Document**

A copy of the thesis, which must be given to all Thesis Examination Committee members, shall:

- Be a finished product and approved by the Research Advisor.
- Conform to the thesis standards of WPI.

The thesis must contain:

- A concise, but comprehensive, *Introduction*.
- A concise, but comprehensive, *Discussion* relating the results presented to the current and future state of the field.
- Intervening pages consisting of either: (i) *Materials and Methods*, and *Results* section or, (ii) the text of a series of articles in manuscript form published in or ready to be submitted to peer-review Journals with the candidate as first author. Work conducted by someone other than the student must be clearly identified and referenced as such in the thesis.
- A comprehensive *Bibliography*.
- An *Abstract*.
- Figures of a quality suitable for publication.

After successful completion of the MS Thesis Examination, the MS thesis document shall be:

- Revised and corrected according to the decisions of the examination committee.
- Signed by all committee members who voted approval of the document and the Research Advisor.
- Submitted to the BME Graduate Studies Committee for administrative approval.
- Submitted in a format suitable for archiving and storage. Students must follow the regulations for preparation of theses published by the library at WPI.

## 5. ME Degree Programs

There are two ME degree programs in BME: The ME Program in Biomedical Engineering, hereafter referred to as the Regular ME Program, and the ME Program in Clinical Engineering, hereafter referred to as the Clinical ME Program. This chapter describes both programs in detail.

### 5.1. Admission Requirements and the Application Process

#### 5.1.1. Admission Requirements

Applicants to either ME program are expected to have an undergraduate degree and a strong background in engineering and mathematics and to achieve basic and advanced knowledge in engineering, life sciences, and biomedical engineering. Admission normally requires a minimum GPA of 3.0 (out of 4.0) and a minimum quantitative score on the Graduate Record Examination of 700. The combined verbal and quantitative score should be at least 1200. Special programs are available for outstanding graduates lacking the necessary prerequisites or with a background in the physical or life sciences. These special programs typically involve an individualized plan of course work at the advanced undergraduate level, with formal admittance to the program following the successful completion of this course work.

#### 5.1.2. Application Procedure

Application to either the Regular or Clinical ME Program must be made through the GSE at WPI. The GSE at WPI (phone: 508-831-5301, email: [gse@wpi.edu](mailto:gse@wpi.edu), <http://www.wpi.edu/Admin/GSE>) accepts both online and paper applications. Online applications are preferred. Requirements for admission include submission of the following:

- A completed *Application for Admission to Graduate Study at WPI*.
- A nonrefundable application fee (waived for WPI alumni)
- Official college transcripts from all accredited degree-granting institutions attended. Admission normally requires a minimum GPA of 3.0 (out of 4.0).
- Three letters of recommendation (and/or other references) from individuals who can comment on the qualifications relevant to the applicant's admission.
- Official GRE scores for the General Test (waived for WPI alumni). Admission normally requires a minimum quantitative score of 700 on the GRE. The combined verbal and quantitative score should be at least 1200.

- TOEFL scores must be submitted by all foreign applicants (waived for foreign students presently attending a U.S. school). TOEFL scores are only valid for two years. A minimum score of 550 on the paper exam or 213 on the computer-based exam is required.
- Statement of Purpose. This is a brief essay discussing background, interests, academic intent, and the reasons the applicant feels he/she would benefit from the ME program in biomedical engineering. For the Clinical ME degree program, this essay should include a discussion of the internship experience and its importance.

Applicants must observe the application and financial aid deadlines imposed by the GSE. The BME Admissions Committee reviews complete applications received by the GSE. Incomplete applications are not generally reviewed.

### **5.1.3. Financial Aid**

Fellowships, research assistantships (RAs), and teaching assistantships (TAs) are available on a competitive basis to outstanding graduate students in the ME Program. Fellowships are awarded by WPI, national organizations, and corporate sponsors. RAs are awarded to graduate students by individual faculty members. TAs are awarded on a competitive basis to support undergraduate teaching in the BME Department at WPI. A decision on financial aid is made separate from and typically follows the admission decision.

### **5.1.4. Provisional Admission**

For outstanding applicants lacking the necessary prerequisites in engineering or with a strong background in the physical or life sciences, provisional admission may be granted to the ME Program. Students who are admitted provisionally must demonstrate, to the satisfaction of the program, a potential to succeed as an ME student before formal admittance is granted. For this, the student:

- Must take a sequence of thematically-related undergraduate and/or graduate engineering courses, such that they demonstrate basic competence at a level of the Bachelor's degree in engineering. Grades of "B" or higher are required.
- Must demonstrate a competence in mathematics. This is most often accomplished by successfully completing (with grades of "B" or higher) a sequence of mathematics courses including differential and integral calculus and differential equations.
- Must demonstrate a knowledge of undergraduate physics. If the student does not have a physics background, course work should include at least General Physics (Mechanics, Electricity and Magnetism, Oscillations and Waves). Grades of "B" or higher are required.

An individualized plan of course work, typically including classes at the advanced undergraduate level, will be developed by the student's Academic Advisor. These courses may be taken at WPI or another approved institution and should be oriented toward engineering students. Provisional students will typically be reviewed and considered for formal admittance into the ME Program after two semesters of course work.

In addition to the course work requirements detailed above, the following points should also be noted for provisional students:

- Institutional fellowships and awards from WPI, including TAs will not be offered. Other types of awards, such as corporate sponsorship or RAs are still possible.
- Important timelines and completion deadlines in the program may be delayed.
- Remedial course work, which is not acceptable for graduate credit, normally cannot be used to meet the degree requirements for the ME Degree.

## **5.2. Summary Degree Requirements**

Students in either ME program must simultaneously satisfy the following degree requirements:

- WPI's General Requirements for All Advanced Degrees.
- WPI's General Requirements for the Master of Science and Master of Engineering Degrees.
- The BME Program's Specific Requirements for the Master of Engineering Degree.

The first two institutional degree requirements are summarized below and detailed in WPI's Graduate Catalog. The BME Program's specific degree requirements are explained fully in this chapter of the

Handbook. These program requirements have been structured to incorporate all institutional degree requirements, so that satisfying the BME Program's degree requirements for the ME will also satisfy the institutional degree requirements. All degree requirements must be satisfied before the degree is awarded.

## **5.2.1. Institutional Degree Requirements**

### **5.2.1.1. WPI's General Requirements for all Advanced Degrees**

All students in either ME program must satisfy the following:

- At the time the degree is awarded, the student must have been admitted to one of the ME programs in Biomedical Engineering.
- A minimum of two-thirds of the required graduate credit for an advanced degree must have been earned at WPI.
- The student must have a program GPA of 3.0 or greater.
- The student must satisfy the graduate rules in effect at a single date between their matriculation date and their graduation date. In applying for graduation (the WPI Graduate Student *Application for Graduation*), the student must specify, by year, which WPI Graduate Catalog contains the rules being satisfied.

After the *Application for Graduation* is submitted, all advanced degrees are subject to the final approval of the CGSR, which determines if the student has satisfied the letter of intent of the requirements for the ME Degree. The CGSR makes its recommendations for the approval of the ME to the WPI faculty, which in turn recommends to the President and Trustees for their final approval the names of students who should be awarded the Master of Engineering Degree in Biomedical Engineering (Regular ME Program) or the Master of Engineering Degree in Clinical Engineering (Clinical ME Program).

### **5.2.1.2. WPI's General Requirements for the Master of Science and Master of Engineering Degrees**

All students in either ME program must satisfy the following:

- The student must obtain a minimum of 30 credit hours of acceptable course or project work. A thesis is not required for the ME degree. (Note: The BME Program's Specific Requirements for the ME Degree requires 33 credit hours of acceptable course or project work).
- The student must obtain a minimum of 21 credit hours of graduate-level courses (18 credit hours for students in the Combined BS/Master's Program), including at least 15 credit hours of graduate-level courses in BME. Other courses (to make up the minimum total of 30 credit hours) may include advanced undergraduate courses approved by the BME Graduate Studies Committee. Such courses are normally considered to be at the 4000 level. The BME Graduate Studies Committee must approve the use of advanced undergraduate courses for the satisfaction of ME degree requirements. A 1/3 unit WPI undergraduate course taken for graduate credit is assigned 3 credit hours of graduate credit. A graduate student registered for graduate credit in an undergraduate course may be assigned additional work at the discretion of the instructor.

## **5.2.2. Summary of the BME Program Requirements for the ME Degree**

While a complete description of the BME Program's Requirements for the ME Degree are provided later in this chapter, the following is a summary of these requirements. All students must satisfy the following:

- Pass the course requirement, which may include directed research credits.
- Fulfill the seminar requirement (for full-time students).
- Fulfill the internship requirement (for students in the Clinical ME Program only).

## **5.2.3. Exceptions and Petitions for Change**

Exceptions to general and specific degree requirements or to other rules may be made, but only by written petition to the Committee on Graduate Studies and Research (CGSR) at WPI. A petition to CGSR should be initiated by the student, but normally should be written on behalf of the student by the BME Graduate Studies Committee.

## **5.3. Committees and Advising**

### 5.3.1. Overview

Various advisors and committees are charged with monitoring and directing the progress of students in the ME program. These advisors and committees are summarized below:

- Academic Advisor – A core BME faculty member at WPI designated to provide the student with counsel and information in the Program.
- Directed Research Advisor – A BME Program Faculty Member charged with mentoring and supporting a directed research project.
- BME Graduate Studies Committee – A committee responsible for administering the ME Program.

In the sections that follow on the various advisors and committees, the following definitions hold:

- BME Program Faculty Member – a faculty member holding a primary appointment at WPI or the Graduate School of Biomedical Sciences (GSBS) at UMMS and formally approved by the BME Graduate Studies Committee. Only a BME Program Faculty Member may serve as a Directed Research Advisor.

### 5.3.2. Academic Advisor

An Academic Advisor advises each student in the ME Program. This advisor meets with the student at least twice yearly, normally just before each academic semester.

#### 5.3.2.1. Duties of the Academic Advisor

- Meet with the incoming ME student during the orientation period to go over *this* Handbook in detail, making sure that everyone understands his/her responsibilities.
- Provide the student with counsel and information.
- Assist the student in selecting a sequence of coursework.
- Advise the student in the selection of any directed research projects.
- Assess progress and approve alterations in proposed course work.
- Provide a written report of the student's status to the BME Graduate Studies Committee following each meeting. The BME Graduate Studies Committee shall distribute the records, after checking them for compliance with the rules and regulations, to the student and a copy shall be kept in the student's file in the Department of Biomedical Engineering at WPI.

#### 5.3.2.2. Selection of the Academic Advisor

The BME Graduate Studies Committee shall appoint the Academic Advisor based on the student's background and research interests. The Academic Advisor must be a core BME Faculty Member at WPI. The student may, at any later time, request a new Academic Advisor.

### 5.3.3. Directed Research Advisor

A Directed Research Advisor supports a directed research project (BE 598). The Directed Research Advisor must be an approved BME Program Faculty Member.

#### 5.3.3.1. Duties of the Directed Research Advisor

- Must demonstrate a reasonable ability to provide adequate financial support for conducting the directed research project.

### 5.3.4. BME Graduate Studies Committee

The BME Graduate Studies Committee is responsible for administering both ME Programs in BME. It acts as a liaison between the faculty and students in the program and the administrative structures at WPI.

#### 5.3.4.1. Duties of the BME Graduate Studies Committee

- Oversees and administers the ME Program.
- Appoints WPI and GSBS faculty as BME Program Faculty Members.
- Selects Academic Advisors for new ME students. An Academic Advisor must be a core BME Faculty Member at WPI.
- Appoints BME Program Faculty Members to different sub-committees, including the Admissions Committee.

- Monitors the progress of students in the ME Program.
- Acts on student and faculty petitions on academic matters.

#### **5.4. Course Requirement**

The ME program has no formal course requirements. Course credits in the ME Program must be distributed across the following categories with the noted minimums:

- Biomedical Engineering (12 credits)
- Life Sciences (6 credits)
- Advanced Engineering Mathematics (6 credits)
- Advanced Courses and Electives (9 credits)

Students may substitute 3 to 6 credits of directed research for 3 credits of biomedical engineering and/or 3 credits of electives. Students in the Clinical ME Program must take “Engineering in the Clinical Environment” (BE 570) and complete a clinical engineering internship for a minimum of 3 credits. Any WPI graduate-level engineering, physics, math, BME, or equivalent course, subject to the approval of the BME Graduate Studies Committee, may be used for Advanced Courses and Electives. The student must obtain a minimum of 21 credit hours of graduate-level courses (18 credit hours for students in the Combined BS/Master’s Program), including at least 15 credit hours of graduate-level courses in BME. Other courses (to make up the minimum total of 33 credit hours) may include advanced undergraduate courses approved by the BME Graduate Studies Committee. Such courses are normally considered to be at the 4000 level. The BME Graduate Studies Committee must approve the use of advanced undergraduate courses for the satisfaction of ME degree requirements and the student’s Academic Advisor may require additional course work to address specific deficiencies in the student’s background.

##### **5.4.1. Standards for Course Grades**

- Students must maintain a GPA of at least 3.0 on a scale of 4.0, where A = 4.0, B = 3.0, C = 2.0, D = 1.0, and F = 0.0. A grade of Pass does not count toward the GPA.
- Students may have a C grade in at most two courses for credit to count towards the ME Degree; no D or F grades are allowed.

##### **5.4.2. Seminar Requirement**

The ME Program requires that all full-time students attend weekly seminars and, in addition, present a seminar once a year. To facilitate this process, students must enroll in *BE 591 – Graduate Seminar*. All ME students are required to pass BE 591 twice. This graduate course is graded pass/fail for zero credits.

##### **5.4.3. Typical Curriculum**

The following are representative examples of course work for different specializations in the ME Program.

###### **5.4.3.1. Bioinstrumentation/Biosensor Specialization**

###### **5.4.3.2. Biomechanics/Biomaterials Specialization**

###### **5.4.3.3. Biomedical Imaging Specialization**

###### **5.4.3.4. Tissue Engineering**

#### **5.5. Directed Research**

Students in either ME Program may elect to participate in an ongoing research project of a BME Program Faculty Member and receive credit towards their ME degree. After an agreement between the student and the Directed Research Advisor is reached, the student registers for BE 598 (Directed Research) and begins a period of research in the Directed Research Advisor’s laboratory.

#### **5.6. Clinical Internship**

For students in the Clinical ME Program, a Rotating Internship is offered during the year. It includes an orientation period to acquaint the student with general hospital organization and procedures, gives a brief exposure to most of the areas listed below and is normally required prior to Specialized Internships. The Specialized Internships involve the student full-time for approximately one month in the ongoing clinical, research, or engineering activities, with supervision by WPI faculty and the internship center staff. To

assure maximum student involvement and supervision, the number of positions at each internship location listed below is limited.

- Anesthesiology, University of Massachusetts Medical School (UMMS).
- Biomedical Engineering, UMASS Memorial Healthcare and UMMS.
- Cardiovascular Medicine, UMMS.
- Surgery, UMMS.

## **6. Combined Bachelor's of Science (BS/MS) / Master's Degree Programs**

There are two combined BS / Master's degree programs in BME: The BS/MS Program in Biomedical Engineering and the BS/ME Combined Program in Biomedical Engineering. This chapter describes these two programs, hereafter referred to as the Combined Program, in detail.

### **6.1. Admission Requirements and the Application Process**

#### **6.1.1. Admission Requirements**

To take advantage of the Combined Program, a student must:

- Be a currently registered WPI undergraduate.
- Successfully participate in and complete a two-step application process, consisting of a course approval process followed by a separate, full application for admission into one of the BME Master's Programs. Completion of the course approval process does not imply or guarantee admittance to the Combined Program.
- Have an equivalent GPA of 3.2 (out of 4.0) in all coursework and a minimum GPA of 3.5 (out of 4.0) in BME coursework at the time of the full application. Because the Combined Program is an accelerated program, only students demonstrating very strong academic skills and potential will be admitted.
- Maintain continuous full-time registration. It is a full-time program of study.

#### **6.1.2. Application Procedure**

Application to the Combined Program is a two-step process: submission of a signed *Course Designation Form* listing the courses that will count toward both degree requirements and a Full Application to one of the BME Master's Programs.

##### **6.1.2.1. Course Approval Process**

On the *Course Designation Form* (available from the Graduate Admissions Office), the student lists the courses that he/she plans to count towards both degrees. A maximum of four courses are allowed, with a maximum of three courses at the 4000-level (the 4<sup>th</sup> course must be a graduate course). These courses must meet the degree requirements for both the Bachelor's and Masters degree and courses designated for graduate students only cannot be listed. This form must bear the signature of each course instructor and be submitted to the Chairman of the BME Graduate Studies Committee for signature no later than the last day of registration for any undergraduate or graduate course to be used for graduate credit. This form will then be forwarded to the Graduate Admissions Office for distribution to course instructors and administrators. A grade of B or better is required for any course to be counted towards both degrees and additional work may be required for undergraduate courses taken for graduate credit. For students in the Combined Program, approved undergraduate courses are assigned graduate credit with a conversion rate of 1/3 WPI undergraduate unit = 3 credit hours, while graduate courses applied toward the undergraduate degree are awarded undergraduate credit with a conversion rate of 1 credit hour = 1/9 undergraduate unit.

The *Course Designation Form* serves two purposes. First, it assures the student that if he/she is admitted into the Combined Program, the courses listed will count towards both degrees. Second, the instructor in each course listed will be formally notified that the course was approved for the Combined Program. The instructor then has a right (but not an obligation) to require additional work of the student. It is important to understand that the approval of this *Course Designation Form* does not guarantee admission to the graduate program, nor does it obligate the student to complete the full application process or enter the program. Students who fail to submit a *Course Designation Form* to the Chairman of the BME Graduate Studies

Committee on time will not be eligible for the Combined Program, but may still apply for one of the regular graduate programs in BME.

#### **6.1.2.2. Formal Application**

The Full Application for the Combined Program follows the same process required of all undergraduate students interested in the BME graduate programs at WPI, with the following modifications:

- GRE scores are not required. However, because acceptance into the Combined Program is competitive and not guaranteed, an interested student should still consider taking the GRE and applying to other graduate programs where the GRE may be required. If desired, GRE scores may be submitted to strengthen an application to the Combined Program.
- The application and transcript fees are waived.
- The application should not be submitted before the student has completed, or is actively involved in, their MQP project. A Full Application submitted earlier than this will not be considered.

The Full Application will be evaluated by the BME Departmental Admissions Committee in exactly the same manner as any application from an undergraduate at another university. A student should not assume that he/she will be admitted to the Combined Program based on approval of the Preliminary Application or submission of the Full Application and should consider and plan for other career options. A student admitted into the Combined Program is considered a graduate student only after the successful completion of the Bachelor's degree.

#### **6.1.3. Financial Aid**

Fellowships, research assistantships (RAs), and teaching assistantships (TAs) are available to outstanding graduate students in the Combined Program. Fellowships are awarded by WPI, national organizations, and corporate sponsors. RAs are awarded to graduate students by individual faculty members. A student requiring financial aid is urged to discuss the possibility of obtaining a fellowship or RA first with their MQP advisor(s), and then with any faculty member with whom they might be interested in working. Teaching assistantships (TAs) are awarded on a competitive basis to support undergraduate teaching in the BME Department. Decisions regarding departmental TAs are made during the spring semester for the following academic year. However, because a TA is required to commit 20 hours per week during the academic year to teaching support, a student with TA support will find it more difficult to finish the Combined Program in 5 years. Students should consider this possibility before accepting a teaching assistantship.

#### **6.2. Additional Information**

Because students in the Combined Program must independently meet the degree requirements for both the Bachelor's and Master's degree, a Combined Program student should consult the appropriate chapter of this Handbook (either MS or ME Degree Program) for more detailed information on the specific BME Graduate Degree Program being sought.

#### **6.3. Summary**

A student interested in the Combined Program should complete the following steps:

1. Early in the junior year, complete and submit a *Course Designation Form* on which the courses to count towards both degrees are listed. This form must bear the necessary signatures. Students who fail to complete this step will not be eligible for the Combined Program, but may apply for the regular graduate programs in BME.
2. For the BS/MS Combined Program option, choose an MQP that can be extended into an MS thesis. Discuss this possibility with your prospective MQP advisor before you sign up. The earlier you start looking, the better your chances of finding the right MQP. Success in the BS/MS program hinges on the ability of the student to extend their MQP project into a quality master's thesis. There is little likelihood that the Combined Program can be completed in 5 years without the MQP as a preliminary effort.
3. Take the GRE general test. While not a requirement for the Combined Program, it may be necessary for other graduate programs.

4. In the fall of your final (senior) year, submit a Full Application for admission to a BME master's program. Remember that you must meet the minimum GPA requirement (3.2 in all coursework and 3.5 in BME coursework).
5. Work hard on your MQP. A strong performance will increase the likelihood that you will be able to complete the BS/MS program in 5 years.

As with all decisions regarding your educational objectives and career, you should discuss the appropriateness of the Combined Program with your academic advisor and knowledgeable colleagues. While there are many advantages to the Combined Program, there are situations where it may not be appropriate. For example, a student who plans to pursue a PhD degree at another institution and has a strong academic record (GPA well above 3.2, GRE scores in the 70th percentile or better) may be better served by skipping the master's degree at WPI.