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INTRODUCTION

This handbook is designed to describe the requirements, policies and procedures that apply to graduate students in the Biomedical Engineering Department. It does not replace the Graduate School Bulletin, but rather it details additional department requirements for the completion of a graduate degree in Biomedical Engineering.

If you have questions concerning the graduate program you should consult the following Information Sources.

- The most recent edition of the **Marquette University Graduate School Bulletin**
- The Department's Director of Graduate Studies (DGS)
- Your academic advisor
- The Department of Biomedical Engineering: Post Office Box 1881, Milwaukee, WI 53201-1881. Telephone: 414-288-3375
- The Graduate School: Holthusen Hall, Room 305, 1324 W. Wisconsin Ave., Milwaukee, WI 53233, 414-288-7137.

The Graduate Programs – M.S., M.E., BS/MS, H.C.T.M. and Ph.D.

The Department of Biomedical Engineering at Marquette University offers two graduate programs in biomedical engineering at the master's level: thesis option (Master of Science, M.S.) and the course-only option (Master of Engineering, M.E.). At the doctoral level, the PhD in Biomedical Engineering is available.

The Department also coordinates two joint programs with the Graduate School of Biomedical Sciences at the Medical College of Wisconsin: the PhD in Functional Imaging, and the M.S. in Healthcare Technologies Management (H.C.T.M).

Any of these programs may be pursued on a full-time or part-time basis. A residency period is required for the doctoral programs.

The accelerated 5-year BS/MS degree program is available to MU students that have demonstrated a capability for high achievement in the undergraduate Biomedical Engineering program. Full-time undergraduate students apply for the program in the Junior year. Accepted students may take graduate level courses for graduate credit and may also take certain upper division undergraduate courses (i.e.: BIEN 5xxx) for graduate credit. Students taking BIEN 5xxx courses must complete the additional work required by the course instructor to receive graduate level credit.

Student Classification.

1. Full-Time.

A student who takes seven or more credits in a regular semester or is otherwise pursuing graduate work on a full-time basis is considered to be a full-time student.

2. Part-Time.

A student who takes six or fewer credits in a regular semester is considered to be a part-time student.

3. Degree Student.

A student is a degree student if enrolled in a program leading to a degree. A student cannot be classified as a degree student unless the department has agreed to accept him or her into a program of study.

a. Regular.

A Regular status student has been admitted to the Graduate School and is working toward a degree in a particular program of study. Such students are eligible for tuition scholarships, graduate assistantships, and fellowships.

b. Probationary.

A student may be admitted to a degree program with probationary status if his or her academic performance is below Graduate School standards but if there is other evidence that he or she has the potential for successful graduate study. Upon completion of nine semester hours of work with an average grade of "B" (3.0) or better (with no grade lower than "C"), at least one-third of which must be at the 6000 course level, the probationary status is removed. A student who fails to remove his or her probationary status on completion of nine semester-hours work will not be permitted to remain in the Graduate School. A student on probation is not eligible to receive financial aid.

4. Non-Degree Student.

A student who chooses this status does not work toward a degree, but credits earned are graduate credits and may be certified as such to school boards or other authorities. Those students seeking non-degree admission must meet the same admission standards as those seeking admission to a degree program. There is no guarantee that credits earned while a non-degree student will later count toward a degree if the student is admitted to a degree program. A student who completes a master's or doctoral degree at Marquette will, upon application, be automatically classified as a non-degree student. Non-degree students may register for any course for which they have met the prerequisites and for which they have department permission.

a. Regular.

A regular student is clearly admissible to the Graduate School but is not seeking a degree.

b. Probationary.

A student whose past academic performance falls below Graduate School standards but shows other evidence of potential for successful graduate work may be granted probationary status. This status is identical to the probationary degree status except that this person is not seeking a degree.

c. Temporary.

A student who seeks to register for graduate courses and who appears to meet Graduate School admission standards but who has not submitted all necessary documentation to the Graduate School that is required for regular admission. Admission to this status is valid for only one semester. A student admitted as a temporary student must apply for and be admitted into one of the other

classifications before he/she will be allowed to register for courses in another semester.

Note: A change from non-degree status to degree status requires a new “Application for Admission” be submitted to the Graduate School.

Areas of Specialization.

Upon enrolling in the master’s or doctoral program in Biomedical Engineering, a student should select his or her area of specialization. Areas include: Biomechanics/Biomaterials, Systems Physiology, Bioinstrumentation/Computers, Functional Imaging, Rehabilitative Bioengineering, and Healthcare Technologies Management. The student’s Academic Advisor and Thesis/Dissertation Director then work with the student to design the appropriate curriculum and research program. This will include courses in engineering, biology, mathematics, and medicine, all of which are integrated with research laboratory experience.

General Requirements.

It is the responsibility of each student to be familiar with, and fulfill all of the requirements outlined below.

1. Academic Load.

The maximum load for a semester is 13 hours of course work. For summer session and inter-session courses, the maximum load is the number of hours equal to the number of weeks in the session. A graduate assistant may register for a maximum of 9 credit hours in a semester. The Dean of the Graduate School must approve all credit overloads.

2. Courses.

Courses numbered 6xxx and above are strictly graduate level courses. Specifically designated “upper division” courses at the 5xxx level may also be taken for graduate credit. For these 5xxx level courses to count toward a graduate degree, a grade of “B” or better is required. Furthermore, it is expected that graduate students in these courses will do extra work beyond that required for undergraduate credit.

3. Required Courses.

In the Master of Science in Biomedical Engineering program, students are required to complete three credit hours of physiology. All doctoral students are expected to successfully complete three credit hours of physiology.

4. Pre-requisite Coursework for Students Enrolling Without Engineering Degree.

Students admitted into the Biomedical Engineering graduate program who do not have an engineering degree must complete prerequisite engineering course work. A list of required courses follows:

- Mathematics: Calculus through Differential Equations
- Programming: Knowledge of C or C++ or FORTRAN or JAVA
- Basic Sciences: Two semesters of Physics [strongly recommended: one semester of Biology]
- Engineering Sciences: 4 courses from the following list of 12, with grade of B or better:

Circuits 1	e.g., EECE 2010	Statics and Dynamics	e.g., MEEN 2122
Circuits 2	e.g., EECE 2020	Materials Science	e.g., MEEN 2460 or 3460
Analog Electronics	e.g., EECE 3030	Mechanics of Materials	e.g., MEEN 2130
Digital Electronics	e.g., EECE 2030	Fluid Dynamics	e.g., MEEN 3320 or 4320
Linear Systems	e.g., EECE 3020	Thermodynamics	e.g., MEEN 3310
Data Structures	e.g., COSC 2010	Computer Hardware	e.g., COEN 4710

5. Independent Study Courses.

Independent study courses (BIEN 6995) are offered for capable and highly motivated students. They are not intended as substitute courses for those offered through the Department of Biomedical Engineering. Rather, they are intended to provide a unique tutorial experience in which topics not covered in the existing curriculum may be explored in detail. Normally only one such course can be used for degree requirements.

a. Approval and Contract

Students taking a BIEN 6995 course must complete, at registration, both an "Approval Form for BIEN 6995" and a "BIEN 6995 Course Contract." Approval is required of the course director, the academic advisor and Chairperson of Biomedical Engineering. The Biomedical Engineering Graduate Committee reviews all BIEN 6995 courses.

b. Summary Report

A summary report including a list of references must be submitted by the student to the Biomedical Engineering Graduate Committee no later than two weeks after the end of classes in the semester in which the course is taken.

6. Undergraduate Students in Graduate Courses

a. Undergraduate Credit.

An undergraduate senior may, with the permission of the Graduate Dean, register for a 6xxx level graduate course for undergraduate credit if the student has a "B" (3.0 or better) average and the current program is such as to allow for involvement in graduate level work. To do so the student must have the written approval of the Chairperson of Biomedical Engineering, the Dean of the College of Engineering and the Graduate School Dean which are given on a form entitled (available in the College of Engineering office): "Petition for Permission to Enroll in a Graduate Level Course in Partial Fulfillment of Undergraduate Degree Requirements."

b. Graduate Credit.

An undergraduate senior may, with the permission of the Graduate School Dean, register for a 5xxx level or 6xxx level graduate course for eventual graduate credit if the student has a "B" (3.0 or better) average. Such courses cannot be used to meet undergraduate degree requirements. Once admitted to a graduate program a student having successfully completed such courses must petition the Graduate School Dean to have these courses count toward the degree requirements. Normally these courses will be accepted, but no guarantee is given, particularly if

the grades received are not appropriate or if the courses do not fit into a unified course program. To register for such courses the student must have the written approval of the Chairperson of Biomedical Engineering, the Dean of the College of Engineering, and the Graduate School Dean, which are provided on the form entitled: "Petition for Permission to Enroll in a Graduate Level Course in Partial Fulfillment of Undergraduate Degree Requirements." The form is available on the Graduate School's website: <http://www.grad.mu.edu/forms/index.shtml>.

c. Application for Degree.

Prior to the deadline posted in the Graduate Bulletin, each student planning to graduate must file an "Application for Degree" with the Graduate School Office.

Advising System.

The advising system is designed to assist and guide the graduate student from the first day of admission into graduate school. The process includes an orientation meeting, distribution of the Graduate Student Handbook and assignment of an academic advisor.

1. Orientation Meeting.

At the beginning of each academic year, all graduate students are required to attend an orientation meeting organized and held by the Department Chairperson. During this meeting, topics including financial aid, general policies, program requirements, special course offerings and areas of research will be presented and discussed.

2. Academic Advisor.

When a student is admitted to the graduate program in Biomedical Engineering, an advisor in his or her area is assigned by the Director of Graduate Studies to assist with any problems and in course selection. The Academic Advisor will assist the student in preparing a coursework plan, and for MS and PhD programs the Academic Advisor will also help the student identify an appropriate Thesis/Dissertation Director.

3. Thesis/Dissertation Director (MS and PhD Programs).

A student selects, with Department approval, his or her Thesis or Dissertation Director. This choice is reflected on the "Master's Thesis Outline Form" or on the "Doctoral Program Planning Form" and "Dissertation Outline Form" as the 'advisor'. The Thesis/Dissertation Director can be designated as the Academic Advisor. A student may have more than one academic advisor, with access to student electronic records. A student must have at least one Academic Advisor who is a primary faculty in the Department of Biomedical Engineering (see program descriptions for MS and PhD programs for committee membership requirements). A student may request an addition or change of Academic Advisor by requesting the change in writing to the Director of Graduate Studies, and providing the names of the current and proposed Academic Advisors. The Director of Graduate Studies will review the request. If the change is allowed, electronic access to the student's records will be given to the new Academic Advisor(s). In those instances in which an advisor is changed after submission of the Thesis Outline Form, Dissertation Outline Form and/or Doctoral Program Planning Form, the student is required to submit a new version or amendment indicating the new advisor. This 'advisor' should be the Thesis or Dissertation Director.

List of Appropriate Forms and Documents.

Students are required to obtain the forms from the Graduate School to ensure that they are the latest versions. Most are available from their Web site (<http://www.grad.mu.edu/forms/index.html>).

1. Available from the Graduate School:

- *Application for Degree*
- *Application for Financial Aid*
- *Continuous Enrollment Registration Form (pdf)*
- *Drop, Add, Audit Form*
- *Master's Degree Transfer Credit Request (pdf)*
- *Master's Thesis Outline Form – Outline for Dissertation, Thesis or Professional Project*
- *Thesis and Professional Project Directives*
- *Doctoral Program Planning Form*
- *Doctoral Program Planning Form Amendment*
- *Doctoral Dissertation Outline – Outline for Dissertation, Thesis or Professional Project*
- *Dissertation Directives*

2. Available from the Department:

- *Approval Form for Independent Study Course BIEN 6995*
- *Independent Study Course Contract*
- *Five Year Bachelor of Science / Master of Science Program Requirements*

If you have questions concerning dates and deadlines, refer to the Marquette University Graduate School Academic Calendar published annually.

It is each student's responsibility to satisfy all program requirements, ensure that all forms are completed and filed appropriately, and that all deadlines are met. All Graduate Students must notify the Biomedical Engineering Office of their intent to graduate at the same time they notify the Graduate School.

MASTER'S DEGREE PROGRAMS

Master of Science Degree in Biomedical Engineering

This degree is awarded in recognition of marked scholarly attainment in a major area of specialization. Students are required to complete a thesis and pass a comprehensive examination.

a. Admission Requirements.

a. Educational Background.

Graduates of accredited colleges or universities that have earned a bachelor's degree in various engineering, physical science or life science disciplines, or equivalent are eligible for admission to the Master of Science Degree program in Biomedical Engineering. Only those applicants whose undergraduate record shows promise of success in graduate study are admitted. To qualify for admission, applicants must have, as a minimum, approximately a "B" average (3.0 GPA) in their total post-secondary school education. Students admitted into the Biomedical Engineering graduate program who do not have an engineering degree must complete prerequisite engineering course work.

b. Application for Admission.

All applicants, regardless of status sought, must submit the following documents at least six weeks in advance of registration with the Graduate School. Normally, no application is considered for admission until it is complete. The required documents are:

- Completed "Application for Admission"
- Official transcripts of undergraduate and graduate records, sent directly to the Graduate School by the issued institution. If a transcript or mark sheet is not in English, the applicant must supply a translation.
- Three letters of recommendation.
- Results of the Graduate Record Examination.
- Application fee (non-refundable).
- International students must submit results of the TOEFL exam.
- Admission is not official until the student is notified in writing of acceptance by the Graduate School. Admission cannot be made final until an official transcript has been received indicating the conferral of an undergraduate degree.
- If a student fails to register for courses within two years after the date of application for admission, the student's file will be discarded.

b. Course Work

A total of thirty credit hours are required. A thesis is mandatory, and a student must register for 6 hours of thesis credit. Of the remaining 24 credits, the following apply:

- At least 9 credits must be taken at the 6xxx level or above (6 credits of which must be in BIEN, exclusive of BIEN 6995 (independent study)).
- A minimum of 12 hours of course work must be taken in Biomedical Engineering, exclusive of 3 credits of BIEN 6995 (independent study).
- A minimum of 3 credits (up to 6 credits) in physiology. This requirement is waived for any student who has successfully completed BIEN 5700, Systems Physiology (or equivalent).
- The remaining courses must be selected from among those that are eligible for graduate credit in science and engineering programs. Up to 3 credits from certain HCTM courses may be counted. They include HCTM 6200 (Biomedical Technology Assessment - 3 credits), HCTM 6300 (Biomedical Technology Standards and Regulations – 2 credits), HCTM 6400 (Ethics of Technology Utilization - 1.5 credits), HCTM 6500 (Product Development of Medical Devices – 2 credits), and HEAL 6840 (Environment of Healthcare Delivery - 2 credits).

a. Transfer of Graduate Credit.

A maximum of 6 semester hours of approved graduate work in a Master's Program from other institutions may be transferred into a student's Master's Program with consent of the Graduate School Dean and the Department Chairperson. Under special circumstances, when courses from other institutions are directly comparable in content to those at Marquette, up to 12 semester hours may be transferred. A course will be considered for transfer credit only if the grade is "B" or better and the course is completed for graduate credit at the institution at which it was taken. Students applying for transfer credit must complete the appropriate form available from the Graduate School Office after completion of at least 6 semester hours at Marquette (9 semester hours if on probation).

b. Independent Study Course (BIEN 6995).

The Biomedical Engineering Graduate Committee reviews all BIEN 6995 courses. A summary report including a list of references must be submitted by the student to the Biomedical Engineering Graduate Committee no later than two weeks after the end of classes in the semester in which the course is completed. A maximum of 3 credits of BIEN 6995 course work is credited toward the 12 hrs of 6xxx level course requirements. Note that (BIEN 6995 cannot be used to satisfy the requirement of 9 credits of 6xxx level BIEN courses).

c. Grades.

Satisfactory academic work is not solely determined by course grades. However, grades are an important factor in the evaluation process. A minimum GPA of 3.0 is required to graduate, and students with a GPA under 3.0 are placed on probationary status. An "I" grade will be regarded as a "C" grade in evaluating academic progress in the Biomedical Engineering Program. Incomplete grades must be cleared by the date specified in the academic calendar or they will automatically become the grade of IP (permanent incomplete).

d. Academic Progress.

The Thesis Director and/or Academic Advisor will submit a biannual academic

progress report to the Department regarding each graduate student. The Chairperson of Biomedical Engineering evaluates the academic progress of all graduate students at the end of each academic semester. If a student is not performing satisfactory work, the student and the Dean of the Graduate School will be notified in writing. The student may be counseled to withdraw or placed on warning. The Dean of the Graduate School will be asked to drop students counseled to withdraw.

e. Thesis Requirements.

Each master's degree student must submit an outline of the proposed thesis on a "Outline for Dissertation, Thesis, Professional Project or Essay" form for approval by the Thesis Director, the Chairperson of Biomedical Engineering, and the Dean of the Graduate School. An acceptable master's degree thesis must meet each of the following four conditions:

- The thesis must reflect the student's originality, creativity, and imaginative work.
- The thesis must demonstrate the student's research ability. This includes (a) a critical analysis of the relevant literature and (b) an engineering contribution to the state of the art or originality in problem solving.
- The thesis must be well written and professionally presented.
- The format of the thesis must follow the "Thesis Directives" issued by the Graduate School.

f. Thesis Committee.

The Thesis Committee is comprised of at least, three members approved by the Department Chairperson. The Director must have a faculty appointment at Marquette University. At least one person on the Committee must be a full-time faculty member in the Department of Biomedical Engineering. Copies of the thesis must be submitted by the student to the Thesis Committee at least two weeks in advance of the thesis defense and oral comprehensive examination.

g. Graduate School Criteria for Serving as Chairperson of a Thesis or Dissertation Committee.

The chairperson of the committee must be a regular faculty member, have competence in the proposed domain area, hold a terminal degree in his or her discipline, and be an active scholar.

h. Thesis Defense and Oral Comprehensive Examination.

All candidates for a master's degree must defend their thesis work to the satisfaction of the thesis committee. Additionally, they must successfully pass a comprehensive examination on the total graduate program of studies. If a student fails the examination, the Department will review the student's entire record, and, if warranted, a second (final) examination will be given. The Comprehensive Exam is normally administered at the time of the Thesis Defense.

The Thesis Director will inform the Chairperson of Biomedical Engineering of the outcome of the examination, who in turn files this information with the Graduate School in a "Master's Comprehensive Exam Report" form. It is the obligation of the student to arrange a time and place on campus for his/her thesis defense and oral comprehensive examination that are suitable for all committee members, and to meet all appropriate deadlines indicated in the Graduate School "Academic Calendar."

i. Time Limitations.

A student must complete all of the requirements for a Master's Degree within six years. If courses from other universities are transferred into a degree program at Marquette and if those courses were taken prior to work at Marquette, the beginning date of the first course will be used to establish the beginning of the student's time period.

j. Learning Objectives.

The Learning Objectives of the Biomedical Engineering Master of Science (M.S.) training program, and their assessment, provide tools that ensure continuous quality improvement. Graduates earning the M.S. degree will be able to:

- **Demonstrate critical thinking skills:** This is measured via the thesis defense and a survey sheet that is completed by each of the thesis committee members. This requires: demonstration of the execution of a well-thought-out research project plan; completion of an independent research experience; ability to critically evaluate work of others in the thesis-related research area.
- **Communication of Technical Information Appropriately for Audience:** This is measured via the thesis defense and a survey sheet that is completed by each of the thesis committee members. This requires: a professional quality oral and graphic presentation; a professional quality written thesis.
- **Demonstrate Technical Proficiency in at least one area of Biomedical Engineering:** This is measured via the thesis defense and a survey that is completed by each of the thesis committee members. This requires: demonstration of factual knowledge of engineering and life science; the ability to critically evaluate the work of others in thesis related research area.
- **Critical Evaluation of the Application of Scientific Methods in Addressing Biomedical Engineering Problems:** This is measured via the thesis defense and a survey that is completed by each of the thesis committee members. This requires: effective use of library and electronic resources for literature research; defensible conclusions and main arguments supported by research; ability to solve interdisciplinary problems.

CHECKLIST for MASTER OF SCIENCE DEGREE in BIOMEDICAL ENGINEERING

Master of Science Students can use the following checklist to assist in course scheduling

- _____ 6 thesis credits BIEN 6999
- _____ 24 non-thesis credit hours (minimum)
- _____ 3 credits in physiology (minimum)
- _____ 12 credits of BIEN courses (minimum) (excludes 6995)
- _____ 9 credits of 6xxx level courses (minimum)
- _____ 6 credits of BIEN or BIOL 6xxx level courses (minimum)
- _____ A minimum GPA of 3.0
- _____ BIEN 6953, Department Seminar, each semester

Five-Year BS/MS Program in Biomedical Engineering.

1. Program Description.

This program allows students to earn both their master of science degree and a bachelor of science in biomedical engineering in five years. Students currently enrolled in the undergraduate biomedical engineering program at Marquette University with a GPA of 3.50 or above may apply for admission to the five-year program during their junior year. Students must submit an application to the Graduate School, indicate their interest in the five-year program, and meet all other admission criteria as stated in the Application Requirements section. GRE test scores must be submitted before the start of the fifth year.

Students may take master's level courses in their senior undergraduate year. These graduate courses (maximum of 9 credit hours) count towards both the undergraduate and graduate degrees. The remaining courses are taken during the students' fifth year. Work on the students' theses research begins the summer between the junior and senior years. Students will continue to gain research laboratory experience the summer between the senior and fifth year, continuing through the final year, culminating in preparation of a written thesis and defense. Upon completion of the first term as master's candidates, students must petition the Graduate School to transfer courses taken as undergraduates to the master's degree.

2. Admission Requirements.

- In Fall semester (usually November), the Chair meets with Junior students that are interested in the 5-yr. BS/MS program or graduate school in general.
- The 5-yr program is available to co-op students. Their eligibility would be determined by where they are in the co-op schedule. For co-op students, there is a change noted below.
- In Spring the Department sends an invitation to apply to the 5-yr program to all juniors with a 3.5 GPA or above.
- Those who are interested complete the regular graduate student admissions packet except for the GRE scores. The GRE must be taken before their 5th year, but not before they apply as juniors.
- These applications are circulated among the Biomedical Engineering Department faculty for acceptance recommendations.
- Students are notified of their admission decisions and are assigned an academic advisor. Note that acceptances are provisional and the student will still need to have a final undergraduate GPA of ≥ 3.0 and "acceptable" GRE scores before they are fully admitted to the Graduate program.

3. Program Requirements.

- Students will be given a welcoming letter from the Department and a course planning form. They will discuss the form and the course choices with their advisor before

choosing Fall senior-level courses. The advisor should keep a copy of this form in the student's file, or it can be kept in the department office, if preferred.

- Students must register for graduate credit in these three senior classes: BIEN 5320 and their two BIEN electives. This is done by filling out a "Permission to Enroll in a Graduate Course" form (available online at the Graduate School website, http://www.marquette.edu/grad/forms_index.shtml). One form has to be filled out for each of the three classes, and must be submitted before registration for the respective class. Note: Co-op students do not receive graduate credit for their co-op experience, so they would take BIEN 5320 and one BIEN elective (6 credits total) for graduate credit.
- Students must take their GRE exam and have scores back to MU before the Fall semester of their 5th year. The GRE is now taken via computer, so a variety of dates are available. They can pick up a GRE Registration bulletin from the Graduate School. This bulletin lists the testing facilities, charges, etc. as well as an application to take the test.
- During the winter break or early in January of their 5th year, students must transfer the 9 graduate credits they took as seniors to their graduate degree program. This is done by filling out a "Master's Degree Transfer of Credit Request" form from the Graduate School. The form cannot be submitted until the student completes one semester of graduate study.
- In the 5th year, students need to register for 7 credits or more to maintain full-time status. These seven credits include thesis credits. If students are not enrolled in at least 7 credits per semester they must fill out a continuous enrollment form (from the Graduate School website), which will maintain their full-time status.
- A total of 30 credit hours of graduate level courses inclusive of thesis credits, 6xxx level and above, and approved upper division undergraduate courses.
- Students apply for graduation using the normal procedures.

N.B.: Awarding any form of financial aid to 5-yr students who have not received their Bachelor's degree yet is not advisable. It is very important to realize that any financial aid offered to an undergraduate student will likely decrease the student's financial aid award by the same amount or more, perhaps doing more harm than good. For this reason, all awards should be discussed in detail with the Graduate School early in the funding decision process.

Master of Engineering (M.E.) Degree in Biomedical Engineering.

This non-thesis degree program includes coursework in existing Biomedical Engineering graduate programs of study, upper division undergraduate courses that carry graduate credit, coursework taken outside of the Department offerings, and performance evaluation via a final written examination (capstone comprehensive written exam).

4. Program Requirements.

- A total of 30 credit hours of graduate level courses, 6xxx level and above, and approved upper division undergraduate courses.
- A minimum of 15 credit hours must be taken in BIEN (Biomedical Engineering) courses.
- Up to 12 credits of upper division undergraduate courses that carry graduate credit may be taken with permission of the M.E. Program Director (Director of Graduate Studies).
- Up to six credit hours may be taken in HCTM (Healthcare Technologies Management) courses.
- Up to two graduate level courses may be taken outside of the Department area with permission of the M.E. Program Director (Director of Graduate Studies).
- One readings course: A faculty member will determine the title and topic, which should link various areas of Biomedical Engineering, e.g. bioinstrumentation, biomechanics, biocomputers, imaging, rehabilitation engineering, biotechnology, bioethics and proper use of human subjects. This requirement can be managed via the existing BIEN 6995 "Independent Readings and Research" course.
- Capstone comprehensive written exam

5. Admission Criteria.

Currently established admissions criteria apply (see below).

a. Basic Requirements.

- A bachelor's degree from a recognized college or university, or the equivalent foreign degree, in engineering or science.
- Ideally, a 3.00 grade point average or better on a 4.00 scale. Graduate admission is based on a number of criteria, and applicants may be admitted with a slightly lower GPA if other criteria indicate future success in the program

b. Detailed Admission Requirements.

- A Bachelor's degree in engineering or science from a recognized college or university.

- Completed graduate school application with accompanying fee.
- Three letters of recommendation - at least one from the current employer.
- A copy of undergraduate transcripts.
- A one-page statement of purpose (Why do you want to earn this degree?).
- The GRE may be required.
- The TOEFL may be required.
- An optional interview with the M.E. Program Director (Director of Graduate Studies) prior to final acceptance into the program.

c. Restrictions on Financial Assistance.

No financial assistance (fellowships, research and teaching assistantships) will be provided to students in the non-thesis degree program. It is assumed that employers will fund the education of these students or they will be self-funded. Students who are enrolled in the current thesis-required program and are receiving funding from the Department of Biomedical Engineering may neither convert nor apply to the non-thesis program.

6. Program Objectives and Requirements.

There are three “core” or common course requirements that are mandated for graduate students in this program for all areas of study. These courses provide students with essential foundational information, as determined by the faculty. The courses provide a means for consistently assessing student and program performance.

a. The three core course requirements.

- *Biomedical Instrumentation:* BIEN 5329 (Upper Division)
- *Physiology:* BIEN 5700 or BIOL 3702 or equivalent (Upper Division)
- *Technical Elective:* HCTM 6200 (Biomedical Technology Assessment) or HCTM 6500 (Product Development of Medical Devices)

b. Learning Objectives.

The Learning Objectives of the Biomedical Engineering Master of Engineering (M.E.) training program, and their assessment, provide tools that ensure continuous quality improvement. Graduates earning the M.E. degree will be able to:

- Synthesize information in the two fields of engineering and life science. This outcome will be measured through the required Readings Course and the capstone comprehensive written examination and evaluated by Program faculty.

- Write an article length paper on interdisciplinary biomedical engineering topics. This outcome will be measured by successful completion of the Readings Course requirement.
- Appropriately communicate technical information to specific audiences. This outcome will be measured via a high technical quality of the Readings Course and via the quality of the capstone written examination evaluated by the program faculty.
- Describe the economic, legal, ethical, and regulatory aspects of healthcare delivery and medical device development. Feedback from employers of ME program graduates, evaluation of student performance in the Readings Course, and a final faculty evaluation of students will be used to measure this outcome.

7. Example Plans of Study for the Master of Engineering Degree.

Students may choose to follow a plan of study that roughly corresponds to one of our existing emphasis areas of graduate study. The sample study plans below reflect the flexibility that is built into the M.E. degree program. Furthermore, these plans are designed for an academic progress pace that is reasonable for students from industry. The existing areas are:

- BioComputers
- BioImaging
- BioInstrumentation
- BioMechanics
- BioRehabilitation.

Refer to the following pages for recommended full-time study plans for each of these areas.

a. A recommended full-time plan for BioComputer focused Master of Engineering studies:

Course	Description	Cred
Fall Semester Year One		
BIEN 5700 or BIOL 3702 or equiv.*	Physiology Requirement	3
BIEN 5320	Biomedical Instrumentation Design	3
Graduate Elective	BIEN, EECE, MATH, etc. as appropriate	3
Spring Semester Year One		
BIEN 5220	Embedded Biomedical Instrumentation	3
Graduate Elective	BIEN, EECE, MATH, etc. as appropriate	3
Summer Session		
HCTM Elective**	HCTM 6300 & 6500 or 6300 & 6400 or 6500 & 6400	3
Fall Semester Year Two		
BIEN 6300	Microprocessor Based Biomedical Instrumentation	3
BIEN BioComputer Elective	Such as BIEN 5610 {160}, 6600 {237}, 6300 {240}, 6310 {249}, 6240 {252}	3
Spring Semester Year Two		
BIEN 6200	Advanced Topics in Biomedical Computing	3
BIEN 6995	Required Readings Course	3

*Credit may be given for having previously completed BIEN 5700 (or equivalent) with a B or better grade.

**Although the credit total for any combination of two HCTM Summer courses is greater than three, only three are needed for the M.E. degree. The actual credit total will appear on the student's transcript.

b. A recommended full-time plan for Biolumaging focused Master of Engineering studies:

Course	Description	Cred
Fall Semester Year One		
BIEN 5700 or BIOL 3702 or equiv.*	Physiology Requirement	3
BIEN 5320	Biomedical Instrumentation Design	3
Graduate Elective	BIEN, EECE, MATH, etc. as appropriate	3
Spring Semester Year One		
BIEN 5500	Medical Imaging Physics	3
Graduate Elective	BIEN, EECE, MATH, etc. as appropriate	3
Summer Session		
HCTM Elective**	HCTM 6300 {211} & 6500 {230} or 6300 {211} & 6400 {212} or 6500 {230} & 6400 {212}	3
Fall Semester Year Two		
BIEN 6210	Biomedical Signal Processing	3
BIEN Biolumaging Elective	Such as BIEN 5610, 5510, 6600, 6320, 6240	3
Spring Semester Year Two		
BIEN 6220		3
BIEN 6995	Required Readings Course	3

*Credit may be given for having previously completed BIEN 5700 (or equivalent) with a B or better grade.

**Although the credit total for any combination of two HCTM Summer courses is greater than three, only three are needed for the M.E. degree. The actual credit total will appear on the student's transcript.

c. A recommended full-time plan for BiolInstrumentation focused Master of Engineering studies:

Course	Description	Cred
Fall Semester Year One		
BIEN 5700 or BIOL 3702 or equiv.*	Physiology Requirement	3
BIEN 5302	Biomedical Instrumentation Design	3
Graduate Elective	BIEN, EECE, MATH, etc. as appropriate	3
Spring Semester Year One		
BIEN 5220	Embedded Biomedical Instrumentation	3
Graduate Elective	BIEN, EECE, MATH, etc. as appropriate	3
Summer Session		
HCTM Elective**	HCTM 6300 & 6500 or 6300 & 6400 or 6500 & 6400	3
Fall Semester Year Two		
BIEN 6310	Microprocessor Based Biomedical Instrumentation	3
BIEN BiolInstrumentation Elective	Such as BIEN 5600, 6600, 6300, 6310, 6390, 6220	3
Spring Semester Year Two		
BIEN 6320	RF Applications in Biomedical Engineering	3
BIEN 6995	Required Readings Course	3

*Credit may be given for having previously completed BIEN 5700 (or equivalent) with a B or better grade.

**Although the credit total for any combination of two HCTM Summer courses is greater than three, only three are needed for the M.E. degree. The actual credit total will appear on the student's transcript.

d. A recommended full-time plan for BioMechanics focused Master of Engineering studies:

Course	Description	Cred
Fall Semester Year One		
BIEN 5700 or BIOL 3702 or equiv.*	Physiology Requirement	3
BIEN 5320	Biomedical Instrumentation Design	3
Graduate Elective	BIEN, MEEN, MATH, etc. as appropriate	3
Spring Semester Year One		
BIEN 5710	Analysis of Physiological Models	3
Graduate Elective	BIEN, MEEN, MATH, etc. as appropriate	3
Summer Session		
HCTM Elective**	HCTM 6300 & 6500 or 6300 & 6400 or 6500 & 6400	3
Fall Semester Year Two		
BIEN 6450	Musculoskeletal Biomechanics 1	3
BIEN BioMechanics Elective	Such as BIEN 5600, 6400, 6410, 6430, 6431, 6600	3
Spring Semester Year Two		
BIEN 6451	Musculoskeletal Biomechanics 2	3
BIEN 6995	Required Readings Course	3

*Credit may be given for having previously completed BIEN 5700 (or equivalent) with a B or better grade.

**Although the credit total for any combination of two HCTM Summer courses is greater than three, only three are needed for the M.E. degree. The actual credit total will appear on the student's transcript.

e. A recommended full-time plan for BioRehabilitation focused Master of Engineering studies:

Course	Description	Cred
Fall Semester Year One		
BIEN 5700 or BIOL 3702 or equiv.*	Physiology Requirement	3
BIEN 5320	Biomedical Instrumentation Design	3
Graduate Elective	BIEN, EECE, MEEN, MATH, etc. as appropriate	3
Spring Semester Year One		
BIEN 5710	Analysis of Physiological Models	3
Graduate Elective	BIEN, EECE, MEEN, MATH, etc. as appropriate	3
Summer Session		
HCTM Elective**	HCTM 6300 & 6500 or 6300 & 6400 or 6500 & 6400	3
Fall Semester Year Two		
BIEN 6610	Rehabilitative Biosystems	3
BIEN BioRehabilitation Elective	Such as BIEN 5600, 5620, 5630, 6600, 6310, 6200, 6210, 6220	3
Spring Semester Year Two		
BIEN 6620	Modeling Rehabilitative Biosystems	3
BIEN 6995	Required Readings Course	3

*Credit may be given for having previously completed BIEN 5700 (or equivalent) with a B or better grade.

**Although the credit total for any combination of two HCTM Summer courses is greater than three, only three are needed for the M.E. degree. The actual credit total will appear on the student's transcript.

Master of Science Degree in Healthcare Technologies Management.

The Healthcare Technologies Management Program is jointly offered by Marquette University and the Medical College of Wisconsin. It is an interdisciplinary graduate program that combines business, technology, and healthcare, and leads to a Master of Science degree in Healthcare Technologies Management from both institutions. The objectives of the program are to:

- Supplement students' technical backgrounds with formal coursework in business and management;
- Develop students' understanding of the economic and regulatory environments of healthcare delivery;
- Prepare students for placement and/or advancement into clinical, industrial, or consulting environments;
- Train engineering professionals capable of managing the design, development, commercialization, and regulatory compliance of medical devices, and the implementation, utilization, and assessment of hospital-based healthcare technologies.

1. Admission Criteria.

a. Educational Background.

Graduates of accredited colleges or universities with a bachelor's degree in various engineering disciplines or equivalent are eligible for admission to the M.S. program in Healthcare Technologies Management. Only those applicants are admitted whose undergraduate record shows promise of success in graduate study. To qualify for admission, applicants must have, as a minimum, approximately a "B" average (3.0 GPA) in their total post-secondary school education.

b. Detailed Admission Requirements.

All applicants, regardless of status sought, must file the following documents at least six weeks in advance of registration with the Graduate School. Normally, no file is considered for admission until it is complete. The materials are:

- "Application for Admission".
- Official transcripts of undergraduate and graduate records, sent directly to the Graduate School by the institution concerned. If a transcript or mark sheet is not in English, the applicant must supply a translation.
- Three letters of recommendation.
- Results of the GRE General (Aptitude), MCAT or GMAT exams.
- Essay describing career goals and reason for interest in program.
- Application fee (non-refundable).
- International students must submit results of the TOEFL exam.
- Admission is not official until the student is notified in writing of acceptance by the Graduate School. Admission cannot be made final until an official transcript has been received indicating the conferral of an undergraduate degree.

- If a student fails to register for courses within two years after the date of application for admission, the student's file will be discarded.

2. Course Work.

The program consists of 15 courses representing 37.5 credit hours. Courses are offered in the evenings to accommodate working engineers and are taught at both institutions. Students may enroll as full or part-time students. Full-time students can complete the program in three semesters. The program includes courses in healthcare technologies management and in business/management. All business courses are taught as part of the Executive MBA program at Marquette University.

3. Required Course Work.

- | | | |
|--------------|--|-------------|
| • HCTM 6100: | Survey of Biomedical Engineering Technology | 3 credits |
| • HEAL 6840: | Environment of Healthcare Delivery | 2 credits |
| • HCTM 6200: | Biomedical Technology Assessment | 3 credits |
| • HCTM 6300: | Biomedical Technology Standards and Regulations | 2 credits |
| • HCTM 6400: | Ethics of Technology Utilization | 1.5 credits |
| • HCTM 6500: | Product Development of Medical Devices | 2 credits |
| • HCTM 6969: | Seminar: Special Topics in Healthcare Technologies Management (1.0 credit - spans two semesters 0.5 credit/semester) | 1 credit |
| • HCTM 6995: | Applied Biomedical Engineering Project (3 credits-spans three semesters-1 credit/semester) | 3 credits |
| • ACCO 6000: | Accounting Foundations | 2 credits |
| • ACCO 6100: | Managerial Accounting | 3 credits |
| • MARK 6100: | Marketing Management | 3 credits |
| • FINA 6100: | Financial Management | 3 credits |
| • MANA 6100: | Organizational Behavior | 3 credits |

4. Transfer of Graduate Credit.

A maximum of 6 semester hours of approved graduate work in a Master's Program from other institutions may be transferred into a student's Master's Program with consent of the Graduate School Dean and the Program Director. Under special circumstances, when courses from other institutions are directly comparable in content to those at Marquette, up to 12 semester hours may be transferred. A course will be considered for transfer credit only if the grade is "B" or better and the course was completed for graduate credit at the institution at which it was taken. Students applying for transfer credit must complete the

appropriate form available from the Graduate School Office after completion of at least 6 semester hours at Marquette (9 if on probation).

5. Independent Study Course HCTM 6995.

During the first semester, students will identify an independent study project or internship involving the management of healthcare technologies, and present it to the faculty for approval. Project selection will be based on the career goals and interests of the student. Faculty and industry/hospital advisors will be available to assist students. Projects will be completed during the third semester and a final report will be presented to program faculty.

6. Electives.

One technical elective and one professional development elective are also required and are chosen according to the student's interests and career goals. All electives must be approved by the Program Director.

7. Grades.

Satisfactory academic work is not solely determined by course grades. However, grades are an important factor in the evaluation process. A GPA of 3.0 is required to graduate, and students with a GPA under 3.0 are placed on probationary status.

8. Time Limitations.

A student must complete all of the requirements for a Master's Degree within six years. If courses from other universities are transferred into a degree program at Marquette and if those courses were taken prior to work at Marquette, the beginning date of the first course will be used to establish the beginning of the student's time period.

9. Learning Outcomes.

The Learning Objectives of the Biomedical Engineering Master of Science in Healthcare Technologies Management (M.S.) training program, and their assessment, provide tools that ensure continuous quality improvement. Upon graduation from the Healthcare Technologies Management Program, all students will have:

- a. acquired knowledge and developed skills needed to manage the personnel and processes required for the
- b. design, development, commercialization, and regulatory compliance of medical devices and
- c. assessment and implementation of hospital-based healthcare technologies,

and will be able to:

- a. apply knowledge of fundamental business operations (marketing, finance, accounting, and organizational behavior) to the management of healthcare technology and
- b. describe the economic, legal, ethical, and regulatory aspects of healthcare delivery and medical device development.

DOCTORAL DEGREE PROGRAMS.

The Doctor of Philosophy degree is conferred in recognition of marked ability and high attainment in the advancement of knowledge and pursuit of truth. It is never awarded solely as a result of course work completed, no matter how faithfully extended over any prescribed period. In defining the requirement for this degree it is convenient to use semester credits, but it should be clearly understood that no number of credits alone entitles a student to this degree. The comprehensive knowledge expected of the student in his or her major field is such that the requirements for the degree usually demand no less than three years of full-time work, or the equivalent beyond the baccalaureate degree.

The Department administers two doctoral programs: the **Doctor of Philosophy in Biomedical Engineering** and the joint **Doctor of Philosophy in Functional Imaging** with the Medical College of Wisconsin. The admission requirements are similar, and all of the above requirements apply to both programs unless stated otherwise. There are differences; for instance the course requirements for the Functional Imaging degree are more structured, and the total credits for the degree are slightly higher (minimum of 65 credits versus 48 credits post-baccalaureate). There may be additional differences - refer to the section "Doctor of Philosophy Degree in Biomedical Engineering."

Doctor of Philosophy Degree in Biomedical Engineering.

Admission Requirements.

1. Educational Background.

Graduates of accredited colleges or universities with a bachelor's degree in various engineering, physical science or life science disciplines or equivalent are eligible for admission to the Ph.D. program in Biomedical Engineering.

Normally, students applying to the doctoral program should complete a Master's Degree prior to beginning work on the doctoral degree. It should be noted that completion of a Master's Degree (even at Marquette) does not insure admission to the doctoral program. Only those students clearly demonstrating the potential to do independent, original, and meaningful work will be admitted. Students with an M.S. from Marquette University must submit a new application to the Graduate School.

Students with a B.S. degree who are admitted directly into the Ph.D. program must complete the M.S. Comprehensive Exam requirements within three semesters after admission into the Ph.D. program. A minimum of 12 credit hours of 6xxx level course work must be completed within this time period. If a student fails the examination, the Department will review the student's entire record, and, if warranted, a second (final) examination will be administered. Failure to pass the second examination will result in termination from the graduate program.

2. Application for Admission.

All applicants for the doctoral program must file the following documents at least six weeks in advance of registration with the Graduate School. Normally, no file is considered for admission until it is complete. The materials are:

- Application for Admission.

- Official transcripts of undergraduate and graduate records, sent directly to the Graduate School by the institution concerned. If a transcript or mark sheet is not in English, the applicant must supply a translation.
- Results of the GRE General (Aptitude).
- Three letters of recommendation including references from recent teachers and supervisors.
- A "statement or purpose" indicating the student's reasons for seeking the doctoral degree, and declaring the student's general area of interest: (Bioinstrumentation/Computers, Biomechanics/Biomaterials, or Systems Physiology).
- Evidence of research ability, if available (e.g. copy of master's thesis, reprints of papers and reports).
- Application fee (non-refundable).
- International students must submit results of TOEFL exam.

Admission is not official until the student is notified in writing of acceptance by the Graduate School.

If a student fails to register for courses within two years after the date of application for admission, the student's file will be discarded.

3. Transfer of Credits.

The transfer of credits completed at the doctoral level at another university is handled on an individual basis. Generally speaking, most Master's level work from an accredited program in a related area will be accepted as part of the doctoral program. Normally, no more than 12 doctoral level credit hours completed at another institution will be accepted as transfer credit into the doctoral program. Any graduate student contemplating course work at another institution to be transferred into the Marquette doctoral program should seek prior approval from the Department of Biomedical Engineering and the Graduate School. Transfer of credit is ordinarily done on the Doctoral Program Planning Form.

Program Requirements.

1. Background Concepts – Ph.D. in Biomedical Engineering.

The PhD degree in Biomedical Engineering is a research degree that is intended to provide the graduate with the breadth and depth of knowledge in one area of concentration within biomedical engineering, and the scientific research training needed for successful careers in academia, biomedical industry, or government. The research training process begins with the student working closely with his or her research advisor and participating in his or her research program. Building on these experiences, the student begins to conduct independent research that eventually leads to an original contribution to Biomedical Engineering. The strength and efficacy of the training process depend to a large extent on the direct interactions of the student with his or her research advisor and on the time the

student spends in the laboratory working on his or her research. The importance of this research training to a PhD degree in Biomedical Engineering is underscored in the following recently revised learning objectives that were developed to evaluate the efficacy of the doctoral program.

- *Conduct independent research that reflects an original contribution to Biomedical Engineering.*
- *Demonstrate technical proficiency in at least one area of Biomedical Engineering.*
- *Recognize need to apply ethical principles in conducting research.*
- *Submit a manuscript for refereed journal.*
- *Demonstrate a commitment to life-long learning by participating in local and national professional development activities on a continuing basis.*

2. Doctoral Requirements Plan.

A program of study leading to the Doctor of Philosophy degree must be prepared by the student in consultation with the student's Dissertation Director. The proposed program of study is outlined on the Doctoral Planning Form and should be submitted to the Graduate School by the student at the end of the student's first semester of study, if possible, but, in any event, no later than the end of the second semester of course work. Normally the total course program exclusive of dissertation will be 36 semester hours beyond the baccalaureate degree. A minimum of **48 semester hours of course work beyond the Bachelor's degree** is required. These 48 credits generally must be taken at Marquette. Course work is accepted as part of a student's doctoral program only after approval of the Doctoral Program Planning Form. The form requires the approval of both the advisor and Department Chairperson, prior to submission to the Graduate School for final approval. Any change to this plan requires approval at all the levels indicated above. The "Doctoral Program Planning Form Amendment Recommendation" is provided for this purpose.

3. Residency Requirement.

The residency requirement should be fulfilled in Biomedical Engineering. The requirement may be satisfied via any one of the following options.

- The student completes 2 semesters of full-time course work (12 hours per semester or its equivalent).
- The student completes 2 semesters of course work (9 hours per semester or its equivalent) while holding a University-controlled traineeship or assistantship, which requires 20 hours of service per week to the University.
- The student completes 3 semesters of course work (9 hours per semester or its equivalent) if he or she accepts work for pay in a non-University-supported job. Approval of this option requires that: (a) the student declare in writing that he or she wishes to follow this option; (b) the letter provide a clear and precise description of the job to be held during the period of residency; (c) the employer certify in writing to the Graduate School that the student's full commitment to the job will not exceed 20 hours of work per week during the residency period; (d) the job itself be closely related to the student's doctoral studies; and (e) the plan be approved by the student's Dissertation Director, Department Chairperson and College of Engineering Dean. Requests to exercise this option and any documents in support of the request should be submitted to the Graduate School.
- In exceptional circumstances and with advance approval from the Dean of the Graduate School, credit toward the residency requirement may be granted to Marquette students

for time spent in doctoral-level research or course work at other institutions. The request for Graduate School approval should include the endorsement of the Biomedical Engineering Department.

- The student who completes 9 or 12 credit hours during Summer Sessions I and II satisfies one semester of the one-year residency requirement; the remaining semester must be completed within the following 12 calendar months.

No residency requirement will be fulfilled during such time as a doctoral student works more than 20 hours per week. Semesters of full-time academic work taken at the master's level at Marquette may be credited toward the residency requirement if the work was done in the same field and was completed reasonably near the beginning of the doctoral studies.

4. Course Work Requirements – Ph.D. in Biomedical Engineering.

A total of 48 graduate credits are required to complete this degree; 36 credits in course work and 12 credits in dissertation. The 36 hours of course work should include formal courses as defined in the MU Graduate Bulletin.

a. Physiology Requirements.

All doctoral students must complete at least 3 credit hours of graduate level physiology. The following are recommended courses that fulfill the physiology requirement.

Course	Title	Credits
BIOL 5701	Advanced Physiology	5
BIOL 5703	Advanced Exercise Physiology	3
BIOL 8702	Systems Physiology	3
BIEN 6720	Human Physiology (MCW)	8

5. Independent Study Course BIEN 6995.

The Biomedical Engineering Graduate Committee reviews all BIEN 6995 course proposals. The proposal specifies the method for documenting successful completion of the course. Appropriate documentation is typically a summary report (with an appropriate list of references) but can also take the form of a completed project (with documentation), formal presentation, examination or other suitable evidence of accomplishment. Completion of each BIEN 6995 course must be documented by the student, approved by the course director and submitted to the Biomedical Engineering Graduate Committee no later than two weeks prior to the end of the semester in which the course is completed.

6. Grades.

Satisfactory academic work is not determined exclusively by course grades. However, grades are one important factor in the evaluation process. The minimal standard for graduation is a GPA of 3.0. Students with a GPA under 3.0 are automatically placed on probationary status. Doctoral students are expected to perform at a higher level.

7. Academic Progress.

- Doctoral students within the Department of Biomedical Engineering shall present a summary of their research progress to their dissertation committee on an annual basis, commencing in the Spring Semester of the second year following admission into the PhD program.

- At the annual meeting (following the student presentation), the dissertation committee shall jointly complete a departmental assessment of graduate student progress. The committee shall make a determination as to whether student progress is satisfactory or unsatisfactory and whether or not the student should be allowed to continue in the program.
- Following the meeting, the dissertation director shall draft a brief summary of student performance (20-100 words) to be submitted with the department assessment to the Graduate Committee for review.
- Based on the assessment of student progress and performance, the Graduate Committee shall recommend to the Biomedical Engineering Department Chairperson as to whether the student is performing satisfactory work. If the student is not performing satisfactory work, the Graduate Committee will recommend one of the following:
 - A probationary period of one year.
 - Transfer to the MS program.
 - Withdrawal from the program.
- If a student is not performing satisfactory work, the student, Dissertation Director, Academic Advisor and the Dean of the Graduate School will be notified in writing by the Department Chair. The student may be placed on probation, advised to transfer to the MS program or counseled to withdraw from graduate studies.
- The Dean of the Graduate School will be asked to drop students counseled to withdraw.

8. Dissertation Outline Form.

Before sitting for the Doctoral Qualifying Exam (DQE), the student must meet with his or her Dissertation Director to identify a Doctoral Committee. The requested committee will be forwarded with the completed Doctoral Dissertation Outline to the BIEN Department Chairperson and the Dean of the Graduate School for review and approval. The Dissertation Outline must be approved by the student's Dissertation Director, the BIEN Department Chairperson, and the Graduate School BEFORE the student can sit for the Qualifying Exam. The student will append a detailed dissertation proposal to the Outline. The dissertation proposal will clearly state the problem to be addressed; give a cogent perspective of the problem relative to the state of the art; discuss the methods proposed to solve the problem, and discuss the expected results. As a guide, the dissertation proposal should be about 10 pages in length. At least 21 days prior to approaching the doctoral committee with a request to sit for the Qualifying Exam, the student is required to send to each committee member an approved copy of the Dissertation Outline.

After the Dissertation Outline is approved, the student should register for the required twelve hours of dissertation credit (BIEN 8999).

The principal focus of the oral exam will be the dissertation proposal. Again, it is to be diagnostic and prognostic. It is recommended that the oral exam not exceed two hours in length.

Each committee member's written report of the candidacy examination results should reflect any areas of weakness in either the oral or the written exam. Prescriptions to address perceived weaknesses in either the oral or the written exam are included in the report.

9. Doctoral Dissertation Committee for Biomedical Engineering.

The Dissertation Committee consists of a Dissertation Director, at least four additional voting committee members and additional advisory committee members, as needed. The Committee must be designed to represent expertise in the research area(s) of the dissertation. Two Committee members must hold regular appointments in the Biomedical Engineering Department at Marquette University, one of which will act as the Dissertation Administrator. The Dissertation Administrator will assure that the appropriate paperwork is filed for the Dissertation and assure that graduation requirements are met. The Dissertation Administrator may also be the Dissertation Director.

A voting Dissertation Committee member without a regular appointment in the Biomedical Engineering Department at Marquette University must meet the following qualifications:

- Curriculum Vitae on file in the Department's Office.
- Approval of the Dissertation Director.
- A terminal degree in the Committee Member's chosen profession.
- Recognized expertise in the area(s) of the dissertation.
- An active scholar.

The Graduate Committee of the Biomedical Engineering Department at Marquette University must approve any exceptions to these qualifications for voting members.

10. The Doctoral Candidacy Exam.

The Doctoral Candidacy Examination consists of two parts. The first part is a written examination, the Doctoral Qualifying Examination (DQE). The second part is an oral examination. The written exam is taken first, and is intended to be both diagnostic and prognostic.

a. Written Examination.

Students entering the Ph.D. program with a Master's degree are required to take a written Doctoral Qualifying Examination (DQE) within the first nine months (2 semesters) after entering the program. Students entering the program with a Bachelor's degree are required to take the DQE at or before the completion of 30 graduate credit hours or completion of a Master's degree, whichever comes first. The written portion of the DQE will be offered at least once per semester. Students intending to take the exam must notify the Chair of the Graduate Committee at least 2 months prior to the end of the semester in which they wish to take the exam. The exam will be designed to cover a breadth of topics within the field biomedical engineering and will be administered by the Chair of the BIEN Graduate Committee in communication with the faculty of the department. The dynamic format of the examination will remain competitive with similar examinations at other research-oriented Biomedical Engineering Departments. The format of the DQE is established by the Graduate Committee. Students scheduled to take the exam will receive written notification of the format at least 2 months prior to the examination date.

Typical Doctoral Qualifying Examination Format (subject to change):

- All students taking the exam will be gathered in one location for an 8-10 hour time period.

- Two multi-part, comprehensive sets of questions will be administered. The first set of questions cover the broad base of topics in the BIEN curriculum (Biocomputing, Biomechanics, Bioelectronics). These questions are submitted to the Graduate Committee by the full-time faculty in the BIEN Department and/or other individuals who have instructed students in appropriate graduate level coursework at Marquette or participating graduate programs (MCW, UWM).
- The second set of questions cover specific topics relative to the student's proposed dissertation. These questions are submitted to the Graduate Committee by the student's dissertation committee members and typically include technical, mathematical, physiological, anatomical, clinical and other appropriate topics.
- The Graduate Committee will select a number of these questions for the DQE.
- Students will provide an answer for a subset of these questions.
- Although the written exam is typically "open book", the student must complete the exam without consultation. Students are generally allowed to bring an unlimited number of written resources to the exam.
- The faculty will evaluate student performance on the first set of questions with a pass or fail.
- The Dissertation Committee under the Direction of the student's Dissertation Advisor will evaluate student performance on the second set of questions with a pass or fail.
- The student will be required to pass a minimum percentage of questions to gain eligibility for advancement to candidacy.
- If the written exam is failed, the student will be given one additional opportunity to retake the exam, normally within 6 months or 2 semesters of the first DQE attempt. If the second examination is unsatisfactory, no further written or oral examination is permitted. Students are evaluated on the basis of their examination results and given specific direction relative to their remaining course work. Those students who fail the second DQE attempt are qualified to complete a Master's degree in Biomedical Engineering through Marquette University. All written questions and answers to the DQE become a part of the student's permanent file in the BIEN Department Office.

b. Oral Examination.

The oral portion of the exam requires that the student present his or her dissertation proposal to faculty and students in the form of a lecture. The student is expected to have prepared the dissertation proposal by the end of their second year. Before the oral examination, the student must have an approved Doctoral Dissertation Outline. The principal focus of the oral exam will be the dissertation proposal, which will consist of a clearly stated problem to be addressed, a cogent perspective of the problem relative to the state of the art, a discussion of the methods to be used to solve the problem, and a discussion of the expected results. The student's dissertation

committee will evaluate the oral presentation and assess the student's ability to complete the proposed work.

11. Public Defense of Dissertation.

An acceptable doctoral dissertation must meet each and all of the following 3 conditions:

- The dissertation must represent an original research contribution as determined by the student's Dissertation Director and Committee members.
- The dissertation must show a high degree of achievement and a clear ability to do independent research.
- The format of the dissertation must follow the "Dissertation Directives" issued by the Graduate School.

When the student and his/her advisor consider the dissertation to be in appropriate form, the student should submit a copy to each member of the Dissertation Committee. This should be done 4 weeks before the scheduled final examination. It is assumed that a dissertation will be reviewed and edited until it meets the approval of all committee members. However, when complete consensus seems impossible to achieve, it will be accepted if the advisor and three other committee members approve. Three copies of the completed dissertation and a "Confidential Report on Dissertation for the Degree of Doctor of Philosophy" form are submitted to the Graduate School.

A public defense of the dissertation (final oral examination) is conducted after the student has completed all other formal requirements for the Ph.D. degree and has submitted the written dissertation to his/her doctoral committee. Although the examination is primarily a defense of the dissertation, it will also include material relevant to the general field in which the dissertation is written, with particular attention to the more recent and significant developments in the field. Because the examination is a public defense, it must be scheduled on campus during weekday working hours, avoiding public or religious holidays. Copies of the dissertation must be distributed to members of the committee at least 4 weeks in advance of the defense. All dissertation defenses will be held in the format of a department seminar. The student will give a formal presentation of work followed by questions invited from all present. Immediately following the seminar, the student will meet privately with the dissertation committee. In this private meeting the committee will address concerns with the written elements of the dissertation.

The student's Dissertation Advisor will inform the BIEN Chairperson of the examination outcome. The Chairperson will forward this information to the Graduate School in a "Dissertation Approval Form" form. It is the obligation of the student to arrange a time and place on campus for the final examination and to prepare an official typed program for the examination at least 4 weeks in advance. This program must follow the format posted in the "Dissertation Directives" and must be submitted to the Graduate School for reproduction and distribution. It is the obligation of the student to meet all appropriate deadlines as indicated in the Graduate School "Academic Calendar."

12. Time Limitations.

All work for doctoral degrees, including the final examination, must be completed within 7 years from the initial registration in graduate courses. A student who enters the doctoral

program with a master's degree in the same field as that in which he/she will pursue the doctoral program must complete the program within 5 years.

13. Learning Objectives.

The Learning Objectives of the Biomedical Engineering Doctor of Philosophy (Ph.D.) training program, and their outcome assessments, provide tools that ensure continuous quality improvement. Graduates earning the Doctorate will be able to:

- Conduct independent research that reflects an original contribution to biomedical engineering: This is measured via evaluation of doctoral dissertation and defense; and a survey sheet that is completed by each of the dissertation committee members. Specifically, the following parameters are evaluated: ability to execute an appropriate research plan; research methods appropriate to the topic; conclusions and main arguments supported by conducted research; effective use of resources to investigate state of current knowledge relative to the research project.
- Technical proficiency in at least one area of biomedical engineering: This is measured via evaluation of doctoral dissertation and defense; and a survey sheet that is completed by each of the dissertation committee members. Specifically, the following parameters are evaluated: demonstration of factual knowledge of engineering and life science; professional quality public presentations of research.
- Recognize the need to apply ethical principles in conducting research: This is measured via evaluation of doctoral dissertation and defense; and a survey sheet that is completed by each of the dissertation committee members. Specifically, the following parameters are evaluated: honest reporting of results and data; proper citing in the dissertation; understanding of plagiarism.
- Evidence of professional development by contributions to local and national professional activities on a continuing basis: This is measured via surveys of the Department's faculty. Specifically, the percentage of students that presented a conference abstract in the previous year is determined. Furthermore, the number of Doctoral students that are members of a technical or professional society is determined and the number of students that published first-authored, peer-reviewed manuscripts is documented.

Doctor of Philosophy Degree in Functional Imaging.

Introduction.

Functional imaging, a means of simultaneously quantifying the structural and functional aspects of a biological system, is an interdisciplinary activity requiring engineering, science, medicine and mathematics. Modern, noninvasive, imaging modalities make functional imaging increasingly practical and present a variety of opportunities for biomedical engineers and clinicians alike.

The Department of Biomedical Engineering at Marquette University and the Biophysics Research Institute at the Medical College of Wisconsin offer a joint degree program in functional imaging that is a PhD level training program for biomedical engineers interested in solving biological and medical problems at the integrative level of physiology. Course offerings and research programs reflect a longstanding collaborative relationship between researchers at Marquette University and the Medical College of Wisconsin. Students are trained as biomedical engineers in the use of imaging technologies to obtain high-resolution structural, kinematic and kinetic data from intact organs as well as in the use of mathematical modeling to understand organ physiology.

A core curriculum stresses training in physiology, bioengineering, biophysics and mathematics. Research is the principal and functional component of student training, whereby students use physical and mathematical approaches to solve biological problems. Through course work, research and scientific presentations, the students will prepare to be independent investigators in the field of biomedical engineering. The importance of this training is underscored in the following learning objectives that were developed to evaluate the efficacy of the doctoral program.

- *Conduct independent research that reflects an original contribution to Biomedical Engineering.*
- *Demonstrate technical proficiency in at least one area of Biomedical Engineering.*
- *Recognize need to apply ethical principles in conducting research.*
- *Submit a manuscript to a refereed journal.*
- *Demonstrate a commitment to life-long learning by participating in local and national professional development activities on a continuing basis.*

1. Admission Requirements.

a. Educational Background.

Graduates of accredited colleges or universities with a bachelor's degree in various engineering, physical science or life science disciplines or equivalent are eligible for admission to the Functional Imaging Ph.D. program in Biomedical Engineering.

Normally, students applying to the doctoral program should complete a Master's Degree prior to beginning work on the doctoral degree. It should be noted that completion of a Master's Degree (even at Marquette) does not insure admission to the doctoral program. Only those students clearly demonstrating the potential to do independent, original, and meaningful work will be admitted. Students with M.S. from Marquette University must submit a new application to the Graduate School.

b. Application for Admission.

All applicants for the doctoral program must file the following documents at least six weeks in advance of registration with the Graduate School. Normally, no file is considered for admission until it is complete. The materials are:

- "Application for Admission".
- Official transcripts of undergraduate and graduate records, sent directly to the Graduate School by the institution concerned. If a transcript or mark sheet is not in English, the applicant must supply a translation.
- Results of the GRE General (Aptitude).
- Three letters of recommendation.
- A "statement or purpose" indicating the student's reasons for seeking the doctoral degree, and declaring the student's general area of interest (Biomechanics/Biomaterials, Systems Physiology, or Bioinstrumentation/Computers).
- Evidence of research ability, if available (e.g., copy of master's thesis, reprints of papers and reports).
- Application fee (non-refundable).
- International students must submit results of TOEFL exam.

Admission is not official until the student is notified in writing of acceptance by the Graduate School.

If a student fails to register for courses within two years after the date of application for admission, the student's file will be discarded.

2. Transfer of Credits.

The transfer of credits completed at the doctoral level at another university is handled on an individual basis. Generally speaking, most Master's level work from an accredited program in a related area will be accepted as part of the doctoral program. Normally, no more than 12 doctoral level credit hours completed at another institution will be accepted as transfer credit into the doctoral program. Any graduate student contemplating course work at another institution to be transferred into the Marquette doctoral program should seek prior approval from the Department of Biomedical Engineering and the Graduate School. Transfer of credit is ordinarily done on the Doctoral Program Planning Form.

Program Requirements.**1. Doctoral Requirements Plan and the Doctoral Planning Form.**

A program of study leading to the Doctor of Philosophy degree must be prepared by the student in consultation with the student's Dissertation Director. The proposed program of study is outlined on the Doctoral Planning Form and should be submitted to the Graduate School by the student at the end of the student's first semester of study, if possible, but, in any event, no later than the end of the second semester of course work. A total of 62 graduate credits are required to complete this degree. These credits are composed of course work (41

credits) and dissertation work (21 credits). The specific credit requirements are discussed in more detail in Section D, and include courses offered at both Marquette University and the Medical College of Wisconsin. The specific Course work is accepted as part of a student's doctoral program only after approval of the Doctoral Program Planning Form. The form requires the approval of both the advisor and Department Chairperson, prior to submission to the Graduate School for final approval. Any change to this plan requires approval at all the levels indicated above. The "Doctoral Program Planning Form Amendment Recommendation" is provided for this purpose.

2. Residency Requirement.

The residency requirement should be fulfilled in Biomedical Engineering. The requirement may be satisfied via one of the following options.

- The student completes 2 semesters of full-time course work (12 hours per semester or its equivalent).
- The student completes 2 semesters of course work (9 hours per semester or its equivalent) while holding a University-controlled traineeship or assistantship, which requires 20 hours of service per week to the University.
- The student completes 3 semesters of course work (9 hours per semester or its equivalent) if he or she accepts work for pay in a non-University-supported job. Approval of this option requires that: (a) the student declares in writing that he or she wishes to follow this option; (b) the letter provides a clear and precise description of the job to be held during the period of residency; (c) the employer certifies in writing to the Graduate School that the student's full commitment to the job will not exceed 20 hours of work per week during the residency period; (d) the job itself is closely related to the student's doctoral studies; and (e) the plan is approved by the student's Dissertation Director, Department Chairperson and College of Engineering Dean. Requests to exercise this option and any documents in support of the request should be submitted to the Graduate School.
- In exceptional circumstances and with advance approval from the Dean of the Graduate School, credit toward the residency requirement may be granted to Marquette students for time spent in doctoral-level research or course work at other institutions. The request for Graduate School approval should include the endorsement of the Biomedical Engineering Department.
- The student who completes 9 or 12 credit hours during Summer Sessions I and II satisfies one semester of the one-year residency requirement; the remaining semester must be completed within the following 12 calendar months.
- No residency requirement will be fulfilled during such time as a doctoral student works more than 20 hours per week. Semesters of full-time academic work taken at the master's level at Marquette may be credited toward the residency requirement if the work was done in the same field and was completed reasonably near the beginning of the doctoral studies.

3. Course Work Requirements - PhD in Functional Imaging.

A total of 62 graduate credits are required to complete this degree. These credits are composed of required courses (26 credits), elective courses (15 credits), and dissertation (research methodologies, research, and seminar) credits (21 credits). There are additional formally required courses for this program, as seen in the following table, **courses offered at MCW are noted with ***.

REQUIRED:	
Physiology	(8 credits)
* Phys 08202 / BIEN 6720	General Human Physiology # (8 cr)
Biophysics/Engineering	(33 credits)
BIEN 6200	Biomedical Signal Processing (3 cr)
BIEN 6500	Mathematics of Medical Imaging (3 cr)
BIEN 5500	Medical Imaging Physics (3 cr)
BIEN 8110	Research Methodology I (3 credits)
BIEN 8120	Research Methodology II (3 credits)
BIEN 8999	Dissertation credits (12 credits)
BIEN 6950	Department Colloquium (3 credits)
*Biophys 03239	Functional MRI Contrast Mechanisms and Applications (3 credits)
Mathematics	(6 credits)
MATH 4720 <i>or</i> *BIOST 200	Statistical Methods (3 cr) <i>or</i> *200 Biostatistics (3 cr)
EECE 6060 <i>or</i> MEEN 6101	Adv Engng Mathematics (3 cr) <i>or</i> Advanced Engng Analysis (3 cr)
# <i>Students are expected to come to the program with the prerequisites for this class.</i>	

ELECTIVES:	
Physiology	(3 credits)
* Phy 08205	Integrated Neuroscience (6 credits)
* Phy 08261	Membrane, Cell and Tissue Transport Physiology (3 credits)
* Phy 08263	Cardiovascular Physiology (3 credits)
* Phy 08266	Respiratory Physiology (3 credits)
* Phy 08267	Advanced Renal Physiology (3 credits)
* Phy 08271	Endocrinology and Metabolism (3 credits)
* Phy 08280	Gastrointestinal Physiology (3 credits)
* Cellbio 01211	Advanced Systems Neuroscience (3 credits)
BIOL 5701	Advanced Physiology (5 credits)

BIOL 5703	Exercise Physiology (3 credits)
BIOL 8702	Cellular Neurophysiology (3 credits)
Biophysics/Engineering	(9 credits)
BIEN 6220	Multidimensional Time Series Analysis (3 credits)
BIEN 5510	Image Processing for the Biomedical Sciences (3 credits)
BIEN 6700	Analysis of Physiological Systems (3 credits)
BIEN 6320	Radio Frequency Applications in Biomedical Eng (3 credits)
* Biophys 03230	Nuclear Magnetic Resonance (3 credits)
* Biophys 03238	Magnetic Resonance Imaging (3 credits)
* Biophys 03240	Fourier Transforms (3 credits)
Mathematics	(3 credits)
MATH 3100	Linear Algebra and Matrix Theory (3 credits, taken for grad cr)
* Biost 201	Biostatistics II (3 credits)
* Biost 201	Nonparametric Statistics (3 credits)

4. Independent Study Course (BIEN 6995).

The Biomedical Engineering Graduate Committee reviews all BIEN 6995 course proposals. The proposal specifies the method for documenting successful completion of the course. Appropriate documentation is typically a summary report (with an appropriate list of references) but can also take the form of a completed project (with documentation), formal presentation, examination or other suitable evidence of accomplishment. Completion of each BIEN 6995 course must be documented by the student, approved by the course director and submitted to the Biomedical Engineering Graduate Committee no later than two weeks prior to the end of the semester in which the course is completed.

5. Grades.

Satisfactory academic work is not determined exclusively by course grades. However, grades are one important factor in the evaluation process. The minimal standard for graduation is a GPA of 3.0. Students with a GPA under 3.0 are automatically placed on probationary status. Doctoral students are expected to perform at a higher level.

6. Academic Progress.

The Dissertation Director and/or Academic Advisor will submit an annual report of progress to the Department regarding each graduate student. The Chairperson of Biomedical Engineering evaluates the academic progress of all graduate students at the end of each semester. If a student is not performing satisfactory work, the student, Dissertation Advisor, Academic Advisor and the Dean of the Graduate School will be notified in writing. The student may be counseled to withdraw from graduate studies or be placed on probation. The Dean of the Graduate School will be asked to drop students counseled to withdraw.

7. Dissertation Outline Form.

Before sitting for the Doctoral Qualifying Exam (DQE), the student must meet with his or her Dissertation Director to identify a Doctoral Committee. The requested committee will be forwarded with the completed Doctoral Dissertation Outline to the BIEN Department Chairperson and the Dean of the Graduate School for review and approval. The Dissertation Outline must be approved by the student's Dissertation Director, the BIEN Department

Chairperson, and the Graduate School BEFORE the student can sit for the Qualifying Exam. The student will append a detailed dissertation proposal to the Outline. The dissertation proposal will clearly state the problem to be addressed; give a cogent perspective of the problem relative to the state of the art; discuss the methods proposed to solve the problem, and discuss the expected results. As a guide, the dissertation proposal should be about 20 pages in length. At least 4 weeks prior to approaching the doctoral committee with a request to sit for the Qualifying Exam, the student is required to send to each committee member an approved copy of the Dissertation Outline.

After the Dissertation Outline is approved, the student should register for the required twelve hours of dissertation credit (BIEN 8999).

The principal focus of the oral exam will be the dissertation proposal. It is to be diagnostic and prognostic. It is recommended that the oral exam not exceed two hours in length.

Each committee member's written report of the candidacy examination results should reflect any areas of weakness in either the oral or the written exam. Prescriptions to address perceived weaknesses in either the oral or the written exam should be included in the report.

8. Doctoral Committee for Functional Imaging.

The Dissertation Committee consists of a Dissertation Director and at least **six** other committee members. The Director and one committee member or two committee members must hold full-time tenure track appointments in Biomedical Engineering and two committee members must hold full-time appointments at MCW and be faculty in the Biophysics Graduate Program. One member must hold a full-time appointment in an outside discipline at MCW and one must hold a full-time appointment in an outside discipline at MU. The final committee member is chosen from either institution, or an outside institution, as is relevant to the student's research areas. The Dissertation Director will assure that the appropriate paperwork is filed for the Dissertation and assure that graduation requirements are met.

In addition, a voting Dissertation Committee member without a regular appointment in the Biomedical Engineering Department at Marquette University must meet the following qualifications:

- Curriculum Vitae on file in the Department's Office.
- Approval of the Dissertation Director.
- A terminal degree in the Committee Member's chosen profession.
- Recognized expertise in the area(s) of the dissertation.
- An active scholar.

The Functional Imaging Graduate Committee of the Biomedical Engineering Department at Marquette University must approve any exceptions to these qualifications for voting members.

9. The Doctoral Candidacy Exam.

The Doctoral Candidacy Examination will consist of two parts. The first part is a written examination, the Doctoral Qualifying Examination (DQE). The second part is an oral examination. The written exam is taken first, and is intended to be both diagnostic and prognostic.

a. Written Examination.

Students entering the Ph.D. program with a Master's degree are required to take the written exam within the first nine months after entering the program. Students entering the program with Bachelor's degree are required to take the written portion before or at completion of 30 graduate credit hours or completion of the Master's degree, whichever comes first. The written portion of the DQE will be offered once per each of the fall and spring semesters. Students intending to take the exam must notify the Chair of the Graduate Committee at least 2 months prior to the end of the semester in which they wish to take the exam. The format of the DQE is established by the Graduate Committee. Students scheduled to take the exam will receive written notification of the format at least 2 months prior to the examination date.

Typical Exam Format (subject to change):

- All students taking the exam will be gathered in one location for an 8-10 hour time period.
- Full-time faculty in the Functional Imaging Program will submit questions for the written exam, which is designed to cover a breadth of topics within biomedical engineering.
- Typically the exam will consist of 8 multi-part questions, with students required to answer 6 of the 8 questions.
- Although the written exam is "open book", the student must complete the exam without consultation. Students are generally allowed to bring an unlimited number of written resources to the exam.
- The faculty will evaluate student performance on each question as a pass or fail.
- The student will be required to pass a minimum of 4 of 6 questions to pass the entire written qualifying exam.

If the written exam is failed, the student will be given one opportunity to retake the exam, normally within 6 months of the first exam attempt. If the second examination is unsatisfactory, no further written or oral examination is permitted. Students are evaluated on the basis of their examination results and given specific direction relative to their remaining course work. Said students are qualified to pursue a Master's degree in Biomedical Engineering through Marquette University. All written questions and answers will become a part of the permanent file in the Department Office.

b. Oral Examination.

The oral portion of the exam process requires that the student present his or her dissertation proposal to the committee in the form of a seminar. The student is expected to have prepared a dissertation proposal by the end of his or her third year. Before the oral portion, the Dissertation Director will recommend a doctoral committee for the student and the students must have his or her Doctoral Dissertation Outline submitted to the committee prior to the seminar (oral exam). The principal focus of the oral exam will be the dissertation proposal, which will consist of a clearly stated problem to be addressed, a cogent perspective of the problem relative to the state of the art, a discussion of methods used to solve the problem, and discussion of expected results. After the presentation, the

student's dissertation committee will evaluate the student's preparation for the completion of the work.

Before sitting for the Qualifying Exam, the student will meet with his or her Dissertation Director to identify a doctoral committee. The requested committee will be forwarded with the completed Doctoral Dissertation Outline to the BIEN Department Chairperson and the Dean of the Graduate School for review and approval. The student will append a detailed dissertation proposal to the Outline. The dissertation proposal will clearly state the problem to be addressed; give a cogent perspective of the problem relative to the state of the art; discuss the methods used to solve the problem, and discuss the expected results. As a guide, the dissertation proposal should be about twenty pages in length. *At least two weeks* prior to approaching the doctoral committee regarding the Qualifying Exam, the student is required to send to each committee member a copy of the Dissertation Outline and the detailed dissertation proposal. The Dissertation Outline must be approved by the student's Dissertation Director, the BIEN Department Chairperson, and the Graduate School; the Dissertation Outline will not be approved before the oral presentation and defense.

After the outline and proposal is approved, the student should register for twelve hours of dissertation credit (BIEN 8999).

The principal focus of the oral exam is the dissertation proposal. Again, it is to be diagnostic and prognostic. It is recommended that the oral exam not exceed two hours in length.

Each committee member's written report of the candidacy examination results should reflect any areas of weakness in either the oral or written exam. Prescriptions to address perceived weaknesses in either the oral or the written exam should be part of the report.

10. Public Defense of Dissertation.

An acceptable doctoral dissertation must meet each of the following three conditions:

- The dissertation must represent an original research contribution as determined by the student's Dissertation Advisor and Committee members.
- The dissertation must show a high degree of achievement and a clear ability to do independent research.
- The format of the dissertation must follow the "Dissertation Directives" issued by the Graduate School.

When the student and his/her advisor consider the dissertation to be in appropriate form, the student should submit a copy to each member of the Dissertation Committee. This should be done 4 weeks before the scheduled final examination. It is assumed that a dissertation will be reviewed and edited until it meets the approval of all committee members. However, when complete consensus seems impossible to achieve, it will be accepted if the advisor and three other committee members approve. Three copies of the completed dissertation and a "Confidential Report on Dissertation for the Degree of Doctor of Philosophy" form are submitted to the Graduate School.

A public defense of the dissertation (final oral examination) is conducted after the student has completed all other formal requirements for the Ph.D. degree and has submitted the written dissertation to his/her doctoral committee. Although the examination is primarily a defense of the dissertation, it will also include material relevant to the general field in which the dissertation is written, with particular attention to the more recent and significant developments in the field. Because the examination is a public defense, it must be scheduled on campus during weekday working hours, avoiding public or religious holidays. Copies of the dissertation must be distributed to members of the committee at least 4 weeks in advance of the defense. All dissertation defenses will be held in the format of a Department Seminar. The student will give a formal presentation of work followed by questions invited from all present. Immediately following the seminar, the student will meet privately with the dissertation committee. In this private meeting the committee will address concerns with the written elements of the dissertation.

The student's Dissertation Director will inform the BIEN Chairperson of the examination outcome. The Chairperson will forward this information to the Graduate School in a "Dissertation Approval Form" form. It is the obligation of the student to arrange a time and place on campus for the final examination and to prepare an official typed program for the examination at least 4 weeks in advance. This program must follow the format posted in the "Dissertation Directives" and must be submitted to the Graduate School for reproduction and distribution. It is the obligation of the student to meet all appropriate deadlines as indicated in the Graduate School "Academic Calendar."

11. Time Limitations.

All work for doctoral degrees, including the final examination, must be completed within 7 years from the initial registration in graduate courses. A student who enters the doctoral program with a master's degree in the same field as that in which he/she will pursue the doctoral program must complete the program within 5 years.

12. Learning Outcomes.

The Learning Objectives of the Biomedical Engineering Doctor of Philosophy (Ph.D.) training program in Functional Imaging, and their assessment, provide tools that ensure continuous quality improvement. Graduates earning the Doctorate in Functional Imaging will be able to:

- Conduct Independent Research that Reflects an Original Contribution to Biomedical Engineering: This is measured via evaluation of doctoral dissertation and defense; and a survey sheet that is completed by each of the dissertation committee members. Specifically, the following parameters are evaluated: ability to execute an appropriate research plan; research methods appropriate to the topic; conclusions and main arguments supported by conducted research; effective use of resources to investigate state of current knowledge relative to the research project.
- Technical Proficiency in at Least One Area of Biomedical Engineering: This is measured via evaluation of doctoral dissertation and defense; and a survey sheet that is completed by each of the dissertation committee members. Specifically, the following parameters are evaluated: demonstration of factual knowledge of engineering and life science; professional quality public presentations of research.

- **Recognize the Need to Apply Ethical Principles in Conducting Research:** This is measured via evaluation of doctoral dissertation and defense; and a survey sheet that is completed by each of the dissertation committee members. Specifically, the following parameters are evaluated: honest reporting of results and data; proper citing in the dissertation; understanding of plagiarism.
- **Submit a Manuscript to a Refereed Journal:** This is measured surveying of the department's faculty. Specifically, the percentage of students that published manuscripts during the previous year is determined.
- **Demonstrate a Commitment to Life-long Learning by Participating in Local and National Professional Development Activities on a Continuing Basis:** This is measured via surveys of the Department's faculty. Specifically, the percentage of students that presented a conference abstract in the previous year is determined. Furthermore, the number of Doctoral students that are members of a technical or professional society is determined and the number of students that participated in life-long learning activities (such as teaching, consulting, seminar attendance; certificates; short courses, etc.) is determined for the previous year.

Grading, Evaluation of Performance.

Grading System.

The letter grades A, AB, B, BC, C, F, W, SC/SNC, UC/UNC, I and X will be assigned for graduate course work at the end of each semester. Detailed explanations of these grades are given in the Marquette University Graduate School Bulletin.

Appeal of Grades.

Any student may consult his or her instructor about the grades received for work done. The exercise of this right neither requires a fixed procedure nor is subject to procedural conditions. Final graduate course grades assigned in the Department of Biomedical Engineering may be appealed following the procedures given below, provided that this action is initiated before the first day of class of the next regular semester following the issuance of the grade.

1. The student must consult with the instructor to determine the reasons for the grade. When there are special circumstances, the Chairperson of the Department of Biomedical Engineering may waive the requirement of consultation with an instructor.
2. When the student is not satisfied with the reasons given by the instructor, he/she may present his/her case in writing to the Chairperson. The student should present all evidence of his/her performance and may request that all other pertinent material be supplied by the instructor.
3. When the Chairperson has examined the appeal and after consultation with the instructor the Chair will: (1) Inform the student that no further department action is to be taken; or (2) convene a committee to review the appeal.
4. The Chairperson will appoint a committee of three regular faculty members of the Department of Biomedical Engineering. The Chairperson may sit on the committee.
5. The committee may proceed from written evidence or may consult the instructor and/or the student according to its judgment.
6. The committee shall give one of three decisions: (1) That the grade given will remain; (2) That the instructor will reconsider the grade in light of what the committee discovered and that the instructor's reconsidered grade will stand; or (3) That the committee recommends a change of grade to the Dean of the Graduate School.
7. The decision of the committee should be the final action inside the Department and any appeal beyond the Department must be made to the Dean of the Graduate School.

Evaluation of Performance.

The Academic Advisor and/or Dissertation Advisor will submit biannual academic progress reports to the Department regarding each graduate student. The Chairperson of Biomedical Engineering evaluates the academic progress of all graduate students at the end of the semester. If a student is not performing satisfactory work, the student and the Dean of the Graduate School will be notified in writing.

The Student may be counseled to withdraw. The Dean of the Graduate School may be asked to place the student on probation, register a voluntary withdrawal, or administratively withdraw students so counseled.

Academic Dishonesty and Research Misconduct.

Upon detection of academic dishonesty, the student involved will automatically receive an "F" grade in the course. Beyond this, additional credit for graduation may be required or expulsion from the school may result depending on the nature of the offense and the Graduate Dean's decision according to University policy. Refer to the Graduate Bulletin for "Definitions of Academic Dishonesty" and its consequences and to the University statement regarding "Research Misconduct".

Registering for Courses at the MCW.

Once you have decided which courses you will be taking at the Medical College of Wisconsin, you must inform the BIEN Department's Administrative Assistant. Take for example the Human Physiology course at the MCW – you would first contact the Administrative Assistant and provide her with the course number, professor, and number of credits. This procedure assures that you get MU credit for taking the class. She will grant consent for you to register. Next, you must register at MU for BIEN 6947. Choose the section that corresponds to the total number of credits you're taking at the MCW that semester. Furthermore, you **MUST** register at the MCW. Your earned grade will show up on your MU transcript. **NOTE:** the MCW classes may start considerably earlier or later than MU classes and the weekly meeting schedule may vary. It is your responsibility to register for BIEN 6947.

Registering for BIEN 6995 and HCTM 6998.

To enroll in BIEN/HCTM 6995/6998, you must fill out both the "Approval for Independent Study Course 6995" and the "BIEN/HCTM 6995/6996/6998 Independent Study Course Contract" forms available in the BIEN Office, Olin 206. The first form must be signed by the Course Director and the Department Chairperson. The second form must be signed by you, the Course Director, and the Department Chairperson. Both forms must be turned in to the BIEN Office at least two weeks before the start of classes.

Continuous Enrollment.

You must request continuous enrollment when you are not registered for any specific course work at MU (when finished with coursework and thesis or dissertation credits, but still doing your research work) or when you are not carrying sufficient course load so as to maintain full-time enrollment status. To request continuous enrollment, you must fill out the "Graduate School Continuous Enrollment Registration Form" and pay the appropriate fee. This completed form must be signed by your advisor and returned to the Biomedical Engineering office, Olin room 206. Consent will be provided for you to enroll. You must register for BIEN/HCTM 9xxx {8xxx} according to the nature of your continuous enrollment. The details are explained on the form, which is included at the end of this handbook. The Bursar will bill you the appropriate fee for continuous enrollment.

Holiday and Leave Policy.

Teaching Assistant, Research Assistant and Research Fellow Holidays and Leave.

Ten-month (academic year) Teaching Assistants and Research Assistants are contracted to work from August 1st to May 31st. Full-time, twelve-month RA's and Research Fellows work 12

months per year. For each week of the 10 or 12 month award, the TA or RA is expected to work a minimum of 20 hours per week beyond the work that pertains to the thesis or to the laboratory course TA assignment. Exceptions include the following holidays: New Year's Day, Martin Luther King Day, Good Friday, Easter Monday, Memorial Day, Independence Day, Labor Day, Thanksgiving, Christmas, and New Year's Eve. These holidays are the University's Administrative holidays, not the Academic (or student) holidays. Twelve month Research Fellows and 12 - month RA's are allowed to take up to 2 weeks vacation per year.

You must discuss any deviations from the above with your thesis/dissertation director.

Financial Aid.

Types of Financial Aid.

Five major categories of financial aid are available to degree-status graduate students in Biomedical Engineering: scholarships, fellowships, teaching assistantships, research assistantships, and loans. Students admitted on probation are not eligible for financial aid, but may be considered once probation has been removed. The term of financial aid is normally for one academic year (10 months), but in some instances may be for one semester (5 months). Limited amounts of financial aid are available during the summer.

Students seeking financial aid other than loans are normally required to submit an "Application for Financial Aid" to the Graduate School no later than February 15 of the academic year prior to the one for which aid is being sought. For more information see http://www.marquette.edu/grad/finaid_index.shtml.

1. Scholarships.

Scholarships are available through the Graduate School. These cover tuition only and range from 1 to 12 credit hours per semester. No service is required of the student in return for a scholarship.

2. Fellowships.

Fellowships are available through the Graduate School. Fellowships provide a stipend and, in some cases, tuition remission. No service is required of the student. Students (especially Doctoral students) are urged to seek the fellowship assistance available from various external government institutes, foundations, and other organizations.

3. Teaching Assistantships.

Teaching assistantships provide students with a stipend and 9 credit hours of tuition remission per semester. In return the students are expected to satisfactorily perform 20 hours of teaching-related assignments per week. Students with teaching assistantships are normally limited to a 9 credit-hour load per semester.

4. Research Assistantships.

Research assistantships also provide students with a stipend and 9 credit hours of tuition remission per semester. In return the students are expected to satisfactorily perform 20 hours of research-related assignments per week. Students with research assistantships are normally limited to a 9 credit-hour load per semester. Research assistantships are also available from individual faculty members with research grants.

5. Loans.

Loan assistance is available to assist qualified students who, without such aid, would be unable to attend the University. Students are eligible for student loans if they are attending the University on at least a half-time basis and are in good academic standing. No applicant will be considered for loan assistance until he/she has been formally admitted to the Graduate School. For specific information on loans and other resources available to graduate students attending Marquette, refer to the Marquette University Financial Aid brochure. This brochure is available from the Office of Student Financial Aid, Marquette University, Milwaukee, WI 53233. Telephone: (414) 288-7390.