

Guide to
Graduate Study in Mechanical Engineering
at

MIT

2008 - 2009 Edition

Department of Mechanical Engineering

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1. The Graduate Program in Mechanical Engineering

The Graduate Program brings together faculty members and post-baccalaureate students into a community of scholars with a common interest in innovation, creativity and advanced professional study. It seeks to provide, in the atmosphere of a professional school, the widest possible opportunity for advanced study and investigation and for intimate association among workers whose common objective is to extend the boundaries of their profession.

The Mechanical Engineering Department offers the following graduate degrees:¹

- (1) Master of Science in Mechanical Engineering (SMME)
- (2) Master of Science in Ocean Engineering (SMOE)
- (3) Master of Science in Naval Architecture and Marine Engineering (SMNAME)
- (4) Master of Science in Oceanographic Engineering (SMOGE, joint MIT/WHOI degree)
- (5) Master of Engineering in Manufacturing
- (6) Mechanical Engineer's (ME) degree
- (7) Naval Engineer's (NE) degree
- (8) Doctor of Philosophy (PhD) or Doctor of Science (ScD), which differs in name only; (this includes the joint MIT/WHOI degrees)

A Master of Science degree is the first graduate degree offered in ME. It is awarded for the completion of a program of advanced study, and a thesis which is considered to be the centerpiece of a student's graduate experience.

The Master of Engineering in Manufacturing is a one-year professional degree program that prepares the student to assume a role of technical leadership in the manufacturing industries.

The Engineer's degree offers preparation for a career in advanced engineering practice. It does so through a program of advanced coursework which goes well beyond the Master's level. This degree is not a stepping stone toward the PhD.

The Doctor of Philosophy (or Science) is the highest academic degree offered. It is awarded for the completion of a program of advanced study and a significant original thesis.

In what follows, we describe how students can gain entry to the ME graduate programs (sections 2 and 3) and what they must accomplish to obtain the various degrees (sections 4-9). Section 10 describes some of the means available at MIT to support graduate students financially.

¹ Students admitted in or before fall 2005 to the 13B program in Ocean Systems Management will be able to pursue their degree objectives at the SM or Doctoral level according to the old Ocean Engineering Department regulations. Their diplomas and degrees will be recommended by the Department of Ocean Engineering following the MIT Bulletin for academic year 2004-2005.

2. Entrance Requirements

Applications to the Mechanical Engineering Graduate School are accepted from persons who have completed, or will have completed by the time they arrive, a Bachelor's degree. Most incoming students will have a degree in mechanical engineering, ocean engineering, or some related branch of engineering. However, the department's admission criteria are not specific, and capable students with backgrounds in different branches of engineering or in science may gain entry.

To qualify for a graduate degree, applicants are expected to have at least an undergraduate-level exposure to most of the core ME disciplines (applied mechanics, fluid mechanics, thermodynamics and heat transfer, materials, control, design and manufacturing), and to be familiar with basic electric circuits and electromagnetic field theory. Those who are deemed deficient may be asked to make up courses in certain areas before they graduate. The makeup courses *may be at the undergraduate level, in which case they are relatively elementary, but usually cannot be applied toward graduate credit*, or at the graduate level, in which case they carry graduate credit.

3. Admission

There are 3 methods of applying to the ME Department.

- Online method – preferred method.
- Download method – download an application, fill out and return to ME Graduate Office, Room 1-112.
- Obtain paper application from Admissions Office, Room 1-103, fill out and return to ME Graduate Office, Room 1-112.

In all cases all official transcripts must be submitted directly to the ME Graduate Office, Room 1-112.

The processing of the applications for graduate study in Mechanical Engineering is, however, done entirely by the Department. The departmental admissions officer, together with a faculty committee, reviews all applications, rank-orders them, and admits the number of applicants that the department expects it can accommodate.

Foreign students applying from abroad may be admitted, but are not permitted to register unless they have full financial support for at least the first year. For most of them this support comes from their family, their government, or some fund or fellowship. Some may, however, become eligible for registration by receiving an offer of a research or teaching assistantship from an individual professor (see section 10).

All applicants are required to take the General Exam part of the Graduate Record Examination (GRE) and submit their scores. Students from non-English-speaking countries are also required to take the IELTS (preferred) or TOEFL exam (phased out by 2010). The minimum acceptable scores for the IELTS exam is 7 and the minimum acceptable scores for the TOEFL is 577/677 for the paper based exam, 233/300 for the computer based exam and 91/120 for the internet based exams.

Applications are due by December 15 of the previous year, and decisions are reported in March.

4. Writing Ability

All incoming graduate students must demonstrate satisfactory English writing ability, or successfully complete appropriate training in writing. This requirement reflects the faculty's conviction that writing is an essential skill for an engineer with an advanced degree.

All incoming graduate students, native as well as foreign, must take the Institute writing ability test which is administered in September. Depending on the results, a student will either (a) pass the writing ability requirement, (b) be required to take a relatively short, but intensive, seminar-workshop in expository writing during the Independent Activities Period in January (21W.794 Technical Writing

Workshop), or (c) be required to take a course in writing. Several courses suitable for engineers and scientists are offered at MIT, and special courses are available for those for whom English is a second language. A student will automatically satisfy the writing ability requirement by taking any of the following subjects: 21F.225 Workshop in Writing for Science and Engineering, 15.280 Communication for Managers, 21W.798 or 21W.799 Special Topics in Writing. If any of these is passed, the student will be excused from taking the writing ability test.

Note that all graduate students for whom English has not been the language of instruction in both elementary and secondary school are also required by MIT to take an English Evaluation Test. This test is separate from the departmental writing ability test.

5. Master of Science Degrees

Writing ability requirement. All incoming graduate students are subject to the writing ability requirement, which is described in section 4.

There are three additional requirements for Master of Science degrees offered by the Department. These pertain to (1) credit units, and (2) thesis. The three Ocean-related Master's degrees also have (3) a distribution requirement. The SMME degree *does not* have a distribution requirement. The specific requirements are as follows:

5.1. Credit units

- Students must successfully complete at least **72 credit units** of coursework, not including credit received for thesis work. Of the 72 units of required coursework, at least **48 must be H-level graduate** subjects. The remaining 24 units may be for G-level subjects, or for certain advanced undergraduate subjects that are not requirements in MIT's undergraduate Mechanical Engineering curriculum.
- The program is expected **to include at least three H-level graduate Course 2 subjects (36 units)**.
- Students must take at least **one graduate mathematics subject (12 units)** offered by the Mathematics Department at MIT. No waivers are allowed.
- A minimum grade point average of 3.5 (A=5, B=4, C=3, D=2, F=0) must be maintained in graduate school.
- Students are allowed to transfer credit toward their Master's degree from graduate subjects taken previously at MIT or another accredited institution, and *not used as part of the credits required for an undergraduate or graduate degree*. **The limit is 24 credit units** if the subjects were taken outside MIT. Transferred subjects must have a grade of B or higher. No thesis units may be transferred.

5.2. Thesis

In the ME Department, the thesis is considered to be the centerpiece of a student's graduate experience. The student must complete an acceptable SM thesis under the supervision of an MIT faculty member or a Senior/Principal Research Scientist/Engineer who holds an appointment in the Mechanical Engineering Department. The thesis is an original work of research, design, or development. The supervisor signs and accepts the thesis upon completion.

If the supervisor is not a member of the Mechanical Engineering Department, a reader who belongs to the Mechanical Engineering faculty must also endorse the thesis. Entering Master's degree candidates

- must notify the ME Graduate Office of their thesis supervisor within six weeks of registration, and
- must submit a completed thesis by a due date set by MIT, typically no later than one week before the beginning of the examination period.

5.3. Distribution Requirements for the Ocean-related Master's Degrees

- **Master of Science in Ocean Engineering: (A graduate subject in each area is required.)** (i) Marine Hydrodynamics (2.20); (ii) A subject that emphasizes professional practice in ocean environment, such as Design Principles for Ocean Vehicles (2.22); and (iii) A subject in Acoustics and Sensing (e.g. 2.066), or Structural Mechanics (e.g. 2.080J), or Structural Dynamics (e.g. 2.060J).
- **Master of Science in Naval Architecture and Marine Engineering:** (i) Marine Hydrodynamics (2.20 or a more advanced subject); and (ii) at least 24 units in their area of concentration. (Background requirements in Introduction to Naval Architecture (e.g., 2.701), and Ship Power and Propulsion (e.g., 2.611) can be waived if taken as an undergraduate; otherwise, these subjects need to be taken at MIT.)
- **Master of Science in Oceanographic Engineering:** Page 7 of the Joint Program Handbook for Oceanographic Engineering list requirements for Master of Science. (Please note that this handbook is currently undergoing revisions)

* * *

A typical Master's degree consists of six twelve-unit subjects plus a thesis, and takes a fulltime student three regular (fall and spring) terms to complete. Students with a research assistantship will not be able to finish in less than this time because of the limitation on the number of subjects they are allowed to take per term (see section 11). At the same time, there is no reason, other than the uncertainties of research, why they should take longer. The faculty believes that a typical Master's degree in Mechanical Engineering should not take longer than one and a half years (three full terms plus the intervening summer) and will strive to implement this duration in its graduate program.

In the ME Department the thesis is considered to be the centerpiece of a student's graduate experience. The Master's thesis is essentially a research (or development, or design) apprenticeship under a faculty supervisor, and as such is usually the major contributor to the student's professional maturation. Incoming students are urged to find a thesis project and supervisor without undue delay. There are several reasons for avoiding delay. For one thing, the SM thesis is a substantial piece of work and takes time to mature. For another, a student who begins thesis work associates him/herself not only with a faculty member, but usually also with a research group or laboratory where he/she meets other faculty and experienced graduate students from whom to learn and get good advice. It is usually a mistake to think that the degree can be attained more efficiently by taking the coursework first, and putting off the thesis work to the last term.

A student's thesis supervisor usually also serves as the academic advisor. If the thesis supervisor is not a Mechanical Engineering Department faculty member, the student should seek academic advice

from an ME faculty member whose research interests are close to his/her own (such as the departmental thesis reader), or from the graduate officer.

5.4. Double SM degrees.

- Students registered in **another engineering department at MIT** who wish to earn a Master of Science in Mechanical Engineering, Ocean Engineering, Naval Architecture and Marine Engineering, or Oceanographic Engineering simultaneously with a Master's degree with specification in their own department may do so by satisfying both departments' requirements, with the credit unit requirements satisfied **separately** (see the MIT Graduate School Manual), but with a common thesis. Such programs of study must, however, be **approved in advance** by the graduate admissions officers of both the departments involved. The ME Department's procedural requirements are the following: (i) The application form for the dual master's degree in the ME Department must be filled out, and adhered to. The student must be *admissible* to the ME Department. (ii) The student must select an ME faculty member as a thesis reader. That faculty member must accept the responsibility **by a letter** to the ME Graduate Admissions Officer. (iii) Items (i) and (ii) must be completed well in advance of thesis completion, but no later than June 1 of the year before the student expects to graduate.
- Students registered in **Mechanical Engineering** who wish to earn a Master of Science in Mechanical Engineering simultaneously with the Ocean-Engineering Master's degrees offered by the Department may do so by satisfying requirements for **both degrees: 144 credit units (at least 96 at the graduate H-level)**, but with a **common thesis**. Such programs of study must, however, be **approved in advance** by the ME Graduate Admissions Officer. The ME Department's procedural requirements are the following: (i) The application form for the dual master's degree in Mechanical Engineering must be filled out, and adhered to. (ii) The ME faculty member who serves as the thesis advisor must accept the responsibility **by a letter** to the ME Graduate Admissions Officer, and ensure that all requirements for the dual degree are met. Items (i) and (ii) must be completed well in advance of thesis completion, but no later than June 1 of the year before the student expects to graduate.

6. Master of Engineering in Manufacturing

The Master of Engineering in Manufacturing is a one-year professional degree program that is intended to prepare the student to assume a role of technical leadership in the manufacturing industries. The degree is aimed at practitioners who will use this knowledge to become leaders in existing as well as emerging manufacturing companies. The curriculum consists of (i) a highly integrated set of 7 lecture/laboratory-based subjects, and a professional seminar for a total of 90 credit units (not including credit received for thesis work); (ii) a thesis project for 24 credit units; and (iii) writing ability. A minimum grade point average of 3.5 must be maintained in graduate school. The following subjects are required, however, exceptions can be made with approval of the M.Eng. in Manufacturing coordinator.

1. **The core subject areas are (90 units):**
 - **Manufacturing Physics (3 subjects):** Manufacturing Materials and Processes (2.810), Analysis Design and Control of Automated Equipment (2.168), Process Optimization and Control (2.830)

- **Manufacturing Systems (3 subjects):** Introduction to Manufacturing Systems (2.853); Supply Chain Planning and Design (15.762+15.763);
 - **Business Fundamentals:** Management for Engineers (2.891)
 - **Plus 1 of the following:** Product Design and Development (2.739J), Product Design (2.744); Precision Machine Design (2.75); Axiomatic Design (2.882); Assembly and Product Design (2.875J)
2. **Professional Seminar in Emerging Manufacturing Industries**
 3. **Thesis Project (24 units)** The thesis project is intended to give each student experience in a manufacturing industry, working on problems with both strategic breadth and technical depth. It is an integrating experience to help pull together the diverse topics treated in class. The projects will explore innovations in technology, systems and business strategy

7. Mechanical Engineer's Degree

The Mechanical Engineer's degree provides an opportunity for further study beyond the Master's level for **those who wish to enter engineering practice** rather than research. This degree emphasizes breadth of knowledge in mechanical engineering and its economic and social implications, and is quite distinct from the PhD, which emphasizes depth and originality of research. The Mechanical Engineer's degree is **not** a stepping stone toward the PhD.

The Engineer's degree has four requirements: (1) writing ability, (2) a program of coursework, (3) thesis, and (4) a qualifying examination. These are described below.

Program of courses. The subject requirements are as follows:

- (1) 162 credit units (including credited units taken during the Master's degree program).
- (2) At least 120 units (including 2.999 - see below) must be graduate H-level subjects.
- (3) At least one subject from eight of the following ten areas:

- | | |
|---------------------------------|-------------------|
| a. Mechanics of Solids | f. Design |
| b. Materials | g. Manufacturing |
| c. Fluid Mechanics | h. Nanotechnology |
| d. Thermodynamics/Heat transfer | i. Energy |
| e. System Dynamics & Control | h. Bioengineering |

- (4) A management/economics requirement of one subject as approved by the Engineer's Degree Subcommittee.

Students entering the Graduate School with a Master's degree are permitted to transfer **no more than 24 units** from another school to the MIT record. No thesis units may be transferred. Subjects being transferred to MIT records should have a grade of B or higher.

Thesis. The thesis may be an extension of a suitable applications-oriented SMME/SOME/SMNAME/SMOGE thesis, or it may be a separate piece of work. An important requirement is that the thesis deal with the solution of real, practical engineering problems, including both their technical and socio-economic aspects. Students are required to submit a specific thesis proposal to the Engineer's Degree Subcommittee shortly after embarking on the program. Students who enter the program with an SM degree from another school must do a separate Engineer's thesis.

Students who do a separate Engineer's thesis, or who are required to extend a previously submitted MIT SMME/SOME/SMNAME/SMOGE thesis, may receive up to a maximum of 12 units of credit for their work. The student's thesis advisor determines the amount of credit. Credit is received by registration of the thesis work as subject 2.999. The credit units for 2.999, not exceeding 12 units, become part of the 162 units total subject requirement.

Qualifying examination. Candidates should take the Engineer's Degree qualifying examination during their first year of residence. These exams are given by the Engineer's Degree Subcommittee, usually in January and May. The examination is an oral one in which the students make a twenty-minute presentation of their thesis proposal and work to date, placing approximately equal emphasis on the technical aspects of the work and on its usefulness in engineering applications in general. Questions on the thesis and related areas will be asked, and the Subcommittee will render its judgment based on both the technical content of the work and its utility in engineering practice.

The qualifying examination for the Engineer's Degree may be waived for candidates with either 3 years military or 5 years industrial post-Bachelor's Degree experience, and with concurrence from the Graduate Officer.

The overall course of study and thesis must comprise a coherent program in Mechanical Engineering. The candidate is required to prepare a plan of study and to submit it to the Graduate Officer for approval by the Engineer's Degree Subcommittee. The student will be considered an Engineer's Degree candidate when this plan is approved.

8. Naval Engineer's Degree

Naval Engineering is considered to include all the arts and sciences as applied in the design, construction and operation of surface and sub-surface marine vehicles. The Naval Engineer's Degree provides an opportunity for further study beyond the Master's level and is intended for those who wish to enter engineering practice, or who plan a career in the design, acquisition, repair and modernization of ships and ship systems. This degree emphasizes breadth of knowledge in naval engineering and is quite distinct from the PhD, which emphasizes depth and originality of research.

Requirements for the Naval Engineer's Degree are identical to those for the Mechanical Engineer's Degree outlined in Section 7 above, with the following differences:

Program of courses. The subject requirements are as follows:

- (1) 162 credit units, including credited units taken during the Master's Degree program.
- (2) At least 120 units (including 2.999, see below) must be graduate H-level subjects.
- (3) At least one subject from eight of the following eleven areas:
(Subjects from various MIT departments are normally taken to satisfy this requirement.)
 - a. Mathematics & Numerical Methods
 - b. Dynamics
 - c. Hydrodynamics
 - d. Materials & Fabrication Technology
 - e. Power and Propulsion
 - f. Probability & Statistics
 - g. Structural Mechanics
 - h. Acoustics
 - i. Ship Production
 - j. Naval Architecture & Systems Eng
 - k. Ship Design

(4) Ship design is an integral part of the Naval Engineer's Degree curriculum. Candidates are required to complete both a conversion design project (2.074) and a 24-credit MIT new major design project (2.705) during their course of study.

Thesis. The thesis may be an extension of a suitable applications-oriented SMME/SOME/SMNAME/SMOGE thesis, or it may be a separate piece of work. An important requirement is that the thesis deal with the solution of real, practical engineering problems, including both their technical and socio-economic aspects. Students are required to submit a specific thesis proposal to the Naval Engineer's Degree Subcommittee shortly after embarking on the program. Students who enter the program with an SM degree from another school must do a separate Engineer's thesis.

Students who do a separate Engineer's thesis, or who are required to extend a previously submitted MIT SMME/SOME/SMNAME/SMOGE thesis, may receive up to a maximum of 12 units of credit for their work. The student's thesis advisor determines the amount of credit. Credit is received by registration of the thesis work as subject 2.999. The credit units for 2.999, not exceeding 12 units, become part of the 162 units total subject requirement.

Qualifying examination.

Candidates should take the Naval Engineer's Degree qualifying examination during their first year of residence. These exams are given by the Naval Engineer's Degree Subcommittee, usually in January and May. The examination is an oral one in which the students make a twenty-minute presentation of their thesis proposal and work to date, placing approximately equal emphasis on the technical aspects of the work and on its usefulness in engineering applications in general. Questions on the thesis and related areas will be asked, and the Subcommittee will render its judgment based on both the technical content of the work and its utility in engineering practice.

The qualifying examination for the Naval Engineer's Degree may be waived for candidates with either 3 years military or 5 years industrial post-Bachelor's Degree experience, and with concurrence from the Graduate Officer.

The overall course of study and thesis must comprise a coherent program in naval engineering. The candidate is required to prepare a plan of study and to submit it to the Graduate Officer for approval by the Engineer's Degree Subcommittee. The student will be considered an Engineer's Degree candidate when this plan is approved.

9. Doctoral Program

The highest academic degree is the Doctor of Science, or Doctor of Philosophy. At MIT, these degrees differ in name only. The doctorate is awarded upon the completion of a program of advanced study, principally at the Institute, and the performance of significant original research, design or development.

Admission into the doctoral program

1. Students from outside MIT may apply to the doctoral program if they have a Master of Science degree. (These applications should be made to the MIT Admissions Office: see section 3).
2. Those who are in the departmental SM program may in principle apply at any time, but they *must* do so before they receive their SM if they expect to continue on without interruption.² The deadline is March 1 for students on the June/September degree list, and November 1 for those on the January degree list. All internal applications should include:

² An application to the doctoral program by an existing SM student implies that the student intends to continue his graduate studies without interruption. If admitted, no immediate (formal or informal) leave of absence/deferment will be granted, and the time for taking the Doctoral Qualifying Examinations will be the same as that for an incoming student with an SM degree from another institution.

- Transcripts; a minimum GPA of 4.5 is required. Applicants with a GPA below 4.5 may be considered for admission if they present evidence of outstanding potential to carry out independent research.
- At least two letters of reference from faculty (one from the SM thesis advisor).
- A statement of objectives.
- Applications should be submitted to the Departmental Graduate Office, Room 1-112.

Note that the qualifying examinations must be taken within three regular terms of the date of admission to the doctoral program (see below).

Requirement for the doctoral degree

The five basic requirements for the doctorate in mechanical engineering are:

- (1) the writing ability requirement, which all graduate students must satisfy,
- (2) the doctoral qualifying examination,
- (3) a major program of advanced study,
- (4) a minor program of study in a field different from that of the major, and
- (5) a thesis.

Details of the five basic requirements are given below, followed by the rules (procedure, schedules, etc.) which pertain to the doctoral program.

Writing ability requirement. All incoming graduate students are subject to the writing ability requirement, which is described in section 4.

Qualifying examinations. The purpose of the qualifying examinations is to determine whether the applicant possesses the attributes of a doctoral candidate: mastery of the mechanical/ocean engineering disciplines and ingenuity and skill in identifying and solving unfamiliar problems.

The qualifying examinations are offered twice yearly (January and May) during a two-week period. All students who are admitted to the doctoral program are eligible to take the qualifying exams, and *must do so (for the first time) before the end of three regular terms (fall and spring) after admission to the PhD program.* There will be no exceptions, except by prior petitioning to the Graduate Officer under special circumstances.

The qualifying examinations consist of two parts:

1. A set of three subject area examinations which candidates may choose from the following approved list (in parenthesis the subject or subjects most suitable for preparation for these exams are included):
 - Dynamics (2.032) **or** Acoustics (2.066)
 - Mechanics of Solid Materials (2.002, 2.071), **or** Structural Mechanics (2.080J)
 - Fluid Mechanics (2.25), **or** Hydrodynamics (2.20), **or** Geophysical Fluid Mechanics (12.800)
 - Thermodynamics (2.42)
 - Heat and Mass Transfer (2.52 or 2.55)

- System Dynamics and Control (2.140 and 2.151) **or** Signal Processing (6.003) **or** Probability and Random Processes (6.431 and 2.22)
- Biological Engineering (2.795J and 2.798J)
- Optics (2.710)
- Manufacturing (2.810)
- Design

2. A thesis area (research)

Both the list of subjects and the format of each subject exam undergo some metamorphosis: New subjects may be made available with one term's advance notice; existing subjects may be discontinued, but only upon at least two years' notice.

The thesis-area examination is currently a forty-five-minute exam in which the candidate presents and is questioned on his/her own original research, such as a previously completed SM thesis or initial work toward the doctoral thesis.

The Mechanical Engineering Faculty as a whole review each student's performance in the qualifying examinations and make decisions regarding passing, being allowed to repeat the exams, or failing. Candidates who are permitted to repeat the exams must do so the next time they are offered. **In no case is a candidate allowed to repeat more than once.**

Major. The major is a program of advanced study which gives the candidate both depth and breadth in a field of engineering or science approved by the departmental Graduate Committee. Examples are: (i) Mechanics; (ii) Product Realization; (iii) Controls, Robotics and Instrumentation; (iv) Energy Science and Engineering; (v) Ocean Science and Engineering; (vi) Biomechanics and Engineering; (vii) Micro/Nanomechanics and Engineering. The Graduate Officer may approve appropriate alternatives.

The set of major subjects should bring candidates to the state of the art in their chosen field, insofar as that is possible via coursework. These subjects are typically H-level. Candidates must satisfy their Doctoral Committee and the Graduate Officer that their proposed program meets this intent. The major represents the principal component of the candidate's coursework.

The program of study comprised of the major, minor, and additional supporting subjects will typically consist of **at least 144 credit units** (12 subjects). Advanced subjects taken toward a Master's degree may be used to satisfy the requirements of the doctorate. Advanced subjects taken at another graduate school may also be counted toward the MIT doctorate, if approved by both the Graduate Officer and the candidate's thesis committee. The limit is 72 credit units if the subjects were taken outside MIT.

Minor. The minor is a program of advanced study that develops competence in an area different from the candidate's principal field of interest. Three subjects (not less than 24 units) must be taken in a coherent field different from the major. These subjects may be taken inside or outside the department. For example, a student whose thesis is in Mechanics may propose a minor in Product Realization, or Biomechanics and Engineering, etc. and take all or most of the subjects within the department.

If the minor is in mechanical engineering or mathematics, all three subjects must be on an advanced graduate level. In other fields, some undergraduate subject content may be acceptable, depending on the remoteness of the field from mechanical engineering and on the prerequisites required for graduate subjects.

Students who have a Bachelor's or Master's degree in a field distinctly different from mechanical engineering may receive complete or partial credit toward the minor. With this exception, all minor subjects must be taken while the student is registered in graduate school.

The minor program must be approved *in advance* by the student's thesis committee and by the Graduate Officer, who places on file a record of the anticipated program as soon as it is formulated. Any subsequent modifications must have the graduate officer's approval. A minimum grade point average of 3.5 must be attained for the subjects which comprise the minor.

PhD Thesis. The thesis is a major, original work which makes a significant contribution in its field. It is the principal component of the doctoral program, and the part that serves as the major indicator of a candidate's abilities.

The thesis is supervised by a faculty advisor and monitored by a doctoral committee, which must include at least three MIT faculty members (including their advisor), and at least two of the three MIT faculty members must be ME faculty.³ The doctoral committee is usually chaired by the thesis advisor, unless the advisor is not a member of the ME faculty, in which case a ME faculty member must chair the committee. *At least one of the committee members must be from outside the research group with which the candidate is associated.* The candidate may also invite qualified people from outside the MIT faculty to serve as additional members of the committee.

Work already accomplished elsewhere, not under the supervision of a member of the MIT faculty, cannot be accepted in full or partial fulfillment of the thesis requirement.

Rules of the doctoral program. The candidate is responsible for initiating the various parts of the program, and for keeping his/her Doctoral Program Record up to date in the departmental Graduate Office. The doctoral program should be undertaken as follows:

1. The student selects an area of principal interest, finds a faculty member who is willing to act as *thesis advisor*, and defines, at least tentatively, an area for the thesis. If the advisor is not in the Mechanical Engineering Department, the student must also find a faculty member from within the department who will act as doctoral committee chair.
2. During the first term after passing the qualifying examinations, the candidate must submit to the Graduate Office a short, tentative *pre-proposal for thesis work*.
3. As soon as possible after that - *and under no circumstances later than the end of the second full term after passing the qualifying examinations* - the student must have the following in place:
 - (a) a doctoral thesis committee,
 - (b) a doctoral thesis proposal,
 - (c) a proposed program of study for the major and minor.

The committee is formed according to the section above, entitled Thesis; *the committee must be approved by the Graduate Officer.* The doctoral committee, together with the thesis advisor, will be the student's primary source of advice and guidance. They will monitor and guide the research and act as mentors in the selection of the major, minor, and additional subjects as the student's education evolves.

The doctoral thesis proposal must be available to the departmental faculty for review and comments. *The proposal is typically limited to six pages of text and figures.* Its purpose is to let the faculty know what the candidate intends to do, and how he/she intends to go about it. It should provide sufficient literature citations to indicate awareness of previous work, and enough detail to show how the work is expected to advance the state-of-the-art. The cover page should carry the student's name, the thesis title, the names of the thesis committee members, and the submission date. Feedback

³ Senior or Principal Research Scientists and Engineers **who hold an appointment in the Mechanical Engineering Department** may supervise PhD students.

from the departmental faculty should be welcomed and taken constructively. All parties should be aware that this is a proposal, and not a doctoral thesis summary. The proposal represents a work in progress, rather than a binding contract; the actual work will be guided and reviewed by the thesis supervisor and the thesis committee, and may evolve in unexpected directions.

We recommend that the candidate have a draft copy of the proposal or pre-proposal ready before choosing a thesis committee, and that it be used to recruit the right people and get feedback on the research plan before distributing the proposal. It is the student's responsibility to provide the Graduate Office with electronic and hard copies of the final proposal, as well as an electronic copy of an abstract of the proposal. The Graduate Office will distribute copies of the abstract to all ME faculty.

The program of study for the major and minor should be entered on the student's Program Record Card (history card). *Students must get signed approval on their history cards for their major and minor list of subjects from the doctoral committee at its first meeting, and then submit it for approval to the Graduate Officer.*

4. The candidate shall arrange meetings with the doctoral committee at least once each (fall and spring) term, and obtain the committee's comments on his/her work. He/she must bring to these meetings the Program Record Card (history card), which is kept on file in the departmental Graduate Office, and the chairman of the committee will make a notation of the meeting on the card. The committee will forward to the graduate officer a recommendation as to whether the candidate may or may not continue doctoral work. A student whose progress is unsatisfactory may be required by the Department, upon a suitable recommendation (typically a U-grade for thesis research) from the student's Thesis Advisor/Thesis Committee, and/or Departmental Graduate Officer, to withdraw from the doctoral program.

5. When the thesis is completed, it shall be presented orally in an **open meeting** of MIT faculty, staff, and students. After the presentation, the thesis is either accepted or rejected by the **departmental faculty members present**.

The thesis presentation is to be scheduled by the doctoral candidate. The student is responsible for obtaining a time and place for the presentation, and for arranging through the Graduate Office to send an announcement of the presentation to each departmental faculty member. ***The thesis defense must be scheduled and announced three weeks in advance.*** One copy of the thesis must be delivered to the Graduate Office, and one copy should be delivered to each member of the doctoral committee ***at least two weeks prior to the presentation.*** The copy in the Graduate Office will be available for the faculty at large.

The thesis must be defended, and the candidate must submit final, archival copies of the thesis to the Graduate Office, by an end-of-term due date established by MIT (see the Graduate Office). If this deadline is not met, the thesis will not be accepted in the current term.

10. Financial Support and Thesis Supervision

Types of financial aid available. The Mechanical Engineering Department offers three types of financial assistance to graduate students; fellowships, research assistantships, and teaching assistantships.

A fellowship provides students with a direct grant, and leaves them open to select their own research project and supervisor. A number of students in the department are supported by fellowships from outside agencies, and a few are available from MIT. However, the department itself has relatively few fellowships to offer.

The majority of students in the ME department are supported by research assistantships, which are appointments to work on particular research projects with particular faculty members. The faculty members procure research grants for various projects, and hire graduate students to carry out the research. The research is almost invariably structured so that it becomes the student's thesis. A fulltime RA appointment provides a full tuition scholarship (i.e. covers all tuition) plus a salary which is adequate

for a single person. In return for a fully-funded education, RAs are required to do a certain amount of work for the grant that funds them. In most cases, this work becomes the student's thesis project. Consistent with this requirement, an RA may register for no more than 24 units of classroom work (typically two subjects) per regular term, and must do at least the equivalent of 24 units of thesis work (i.e. research on the project) per term. The summer term is usually spent on thesis work.

Teaching assistants are appointed to work on specific subjects of instruction. As the name implies, TAs usually assist a faculty member in teaching, often grading homework problems and tutoring students. In the Mechanical Engineering Department, TAs are seldom used for regular full-time classroom teaching. TAs are limited to 24 units of credit per regular term, *including both classroom subjects and thesis*. A TA appointment usually does not extend through the summer.

Experience has shown that the optimum graduate program consists of about equal measures of coursework and research, consistent with an RA appointment. One advantage of a fellowship is greater freedom in choosing a research project and supervisor. Another is that, unlike an RA, a fellowship student is not limited to two courses per term, and may therefore be able to finish a degree in a somewhat shorter time.

A teaching assistantship gives the student teaching experience, and can also be extremely valuable for reviewing basic subject material: for example, in preparation for the doctoral general exams. It does not, however, leave much time for thesis research, and may extend the time that the student will need to complete a degree.

How to get a Research Assistantship or Teaching Assistantship. Once a student is formally admitted to the Department, he/she is eligible for an assistantship. At this point it helps to understand how the funding of graduate research works in MIT's Engineering School. The faculty write proposals for specific research, and when they receive funding, they hire graduate Research Assistants to do the research with/for them. The departmental Graduate Office distributes lists of admitted students to all faculty members, noting each student's interests, previous university affiliation, grade point average, etc. From these lists, the faculty select candidates for the positions they have available. They make their final selections after reviewing the students' application files. At that point, they contact a student, with a specific offer for a research assistantship. A particular student may get offers from several professors, in which case he/she has to make a choice about which one to accept.

The graduate research enterprise is thus somewhat like a free enterprise system, with the individual professors looking for the best students for their research projects, and the students looking for the most interesting or satisfying research experience.

What can students who have just been accepted do to improve the chances in this process? The first step is to carefully read the Research areas as listed on the ME website meche.mit.edu. From these areas students can identify the faculty members they would like to work with, and should feel free to write, e-mail, or telephone them; they should not be shy about making the professors aware of any special qualifications that they (the students) might possess (previous research experience, etc.).

A small fraction of the incoming students - those judged by the Department to be the best prospects - receive *guaranteed offers* of assistantships shortly after being accepted. This means simply that the Department guarantees that they will receive a full RA or TA for their first academic year. Note, however, that each of these students still has to accept a particular position from among the offers that are made to them by individual faculty members. If they wish to work with particular faculty, they should feel free to contact them and inquire about the availability of positions, just like the students who have not received guaranteed offers.

Students seeking research assistantships should be aware that many, if not most, commitments are made after April 15. Positions become available through the spring and summer, depending on when the research grants come in, and a significant fraction of new research assistantship offers are made after the beginning of the fall term. Most graduate students end up with funding by the end of their first term.

Teaching Assistantships are relatively few in number, and are usually offered to students who are already at MIT and known to the departmental faculty. A student who has a keen interest in serving as a TA in a particular subject can make it known by contacting the faculty member in charge (listed in the MIT Bulletin under the description of each subject).

How to find a thesis supervisor if you have independent funding. Students who have fellowships or are privately funded need to associate themselves with a faculty member who will supervise their thesis research. They should choose a supervisor in much the same way as another student would try to secure an RA, identifying prospective faculty members from the Thesis Topics list and checking whether there are projects they can work on. Research requires money, and even though these students require no salary from the Department, they are well advised to find a supervisor who has some funding for the intended work. Although their obligations to the research are not the same as those of an RA, in practice they end up working just as hard in order to finish their theses in a reasonable time. It is usually a good idea to associate with a supervisor as soon as possible after arrival at MIT. The student then becomes part of a research group, gets a desk to work at, and is in a position to get advice and learn from his/her supervisor and from the more experienced students in the research group.

Rules for students who do thesis work off-campus. *All such students are required to have an ME faculty member as either thesis supervisor or co-supervisor.* Prior to embarking on work away from campus, a student must submit to the Graduate Officer a plan for finishing the degree, including thesis topic, timetable of academic courses at MIT, timetable of planned non-residential periods, and names and coordinates of off-campus supervisors. Both the thesis advisor and the Graduate Officer must approve the plan by signature. Students with off-campus co-supervisors (SM as well as PhD candidates) must arrange joint meetings with both their on- and off-campus supervisors at least once every regular term.