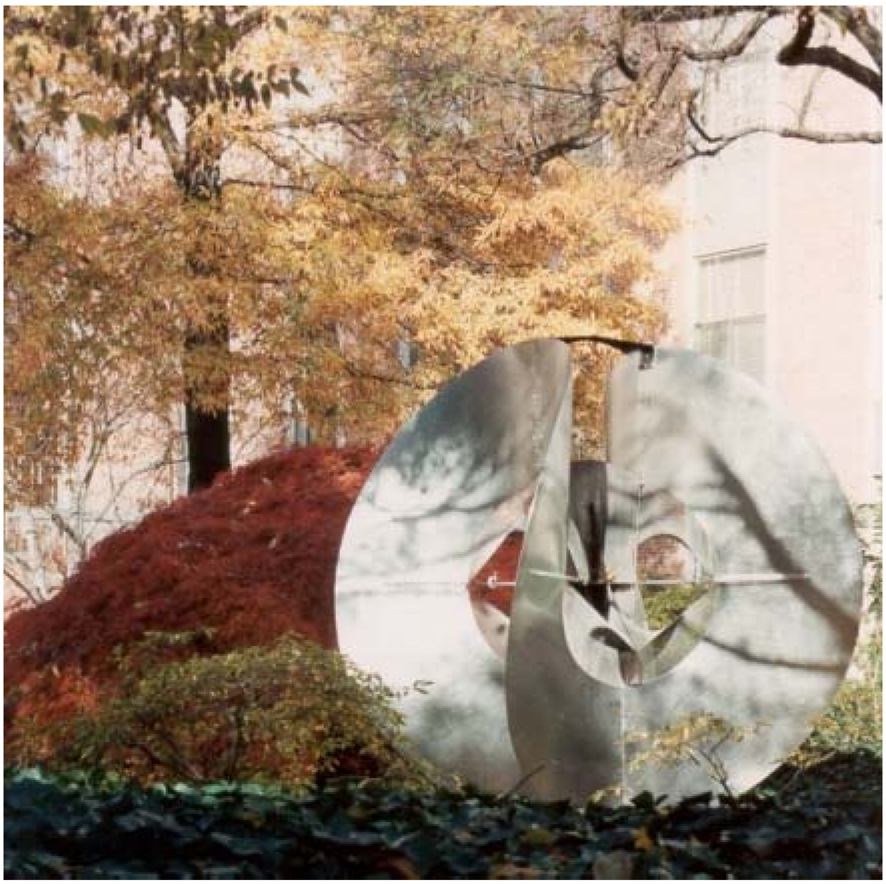
PRINCETON UNIVERSITY

Department of Mechanical and Aerospace Engineering

INFORMATION FOR GUIDANCE OF GRADUATE STUDENTS



2008-09 Edition

The information provided in this guide was developed with the assistance of the Graduate Student Committee and supercedes all prior documents. Its contents have been approved by the MAE Faculty and represent the Department's graduate education policy. All required forms referenced in this guide may be found at the MAE Departmental website.

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1. Introduction

The Department offers three programs of graduate study and research, Doctor of Philosophy (Ph.D.); Master of Science in Engineering (MSE); and Master of Engineering (MEng). The Ph.D. is a five-year program designed for a career in basic research and teaching. The MSE is a 2 year program designed for a career in industrial, non-government organizations, or government research and development and requires an original thesis. The MEng typically is a 1 year full time program designed for those students seeking to obtain the rigorous and advanced training needed in the applied aspects of modern technology and does not require a thesis.

This document outlines the procedures prescribed by the Department for each of these programs and includes other relevant rules and practices. In general, the Departmental procedures comply with the rules of the Graduate School as presented in the **Graduate School Announcement**. Additional useful information can be found in the **Rights, Rules, and Responsibilities** booklet issued by the Graduate School.

2. The MAE Graduate Research Areas

2.1 Combustion, Propulsion, and Energy Conversion.

Worldwide energy and emissions concerns demand extensive and detailed studies of fuel-conversion processes. Combustion is critical to power generation, propulsion, air and ground transportation, and the environment. This area of study includes combustion of conventional, alternate, and high-energy-density fuels; pyrolysis of coal and organic materials; practical combustion for application in furnaces, gas turbines, and reciprocating engines; pollutant generation and control; combustion synthesis of materials; waste incineration; supercritical combustion; supersonic propulsion; turbulent combustion; spray and dust combustion; microgravity combustion; gas and condensed-phase chemical kinetics; heat and mass transfer; combustion theory; computational combustion; and laser diagnostics of combustion phenomena.
Faculty: Dryer, Ju, Law, Socolow

2.2 Computational Engineering

Computation is a key tool that helps translate the growing understanding of the physics of fluids and solids to the design of the next generation of vehicles and manufacturing systems. In the materials arena, computational research is centered around theoretical and computational aspects of materials science, establishing protocols for modeling structural evolution and thermomechanical behavior across multiple-length scales. Computational fluid mechanics is concerned with the simulation of viscous flow past complex configurations with application to aircraft and ship design. Once the flow characteristics are well understood, the techniques may be applied to optimize the shape of a structure over which the fluid is flowing.
Faculty: Carter, Haataja, Holmes, Martin, Martinelli, Rowley

2.3 Dynamics and Control Systems

The analysis of nonlinear dynamic systems, and techniques for controlling complex systems using feedback, play important roles in many aspects of engineering. Ongoing research at Princeton in this area includes nonlinear dynamical systems, bifurcation theory, low order modeling, optimal control and estimation, multiscale modeling, nonlinear control, and geometric mechanics. Applications and current research projects include dynamics and neuromechanics of insect locomotion; underwater locomotion, including fish, eels, and underwater gliders; cooperative control, mobile sensor networks, and adaptive ocean sampling; collective motion of animal groups; modeling and control of fluids; control of unsteady aerodynamics for micro-air vehicles; geometric integrators; orbital mechanics and space mission design; adaptive optics for ground and space telescopes; modeling cognitive and other neurobiological processes; methods for cancer detection; and optimal control of disease processes.
Faculty: Holmes, Kasdin, Leonard, Littman, Rowley, Stengel

2.4 Energy and Climate

The MAE department is deeply involved in the University-wide Carbon Mitigation Initiative, an interdepartmental program studying the challenge of reducing the rate of global emissions of carbon dioxide. One of the MAE faculty members is the co-director of the program, and several graduate students are involved as well. Work based in mechanical engineering addresses the modifications of power plants and synthetic fuels plants necessary to capture CO2, alternative

fuels with lower carbon content for mobile and stationary applications, and wind and biomass energy conversion. Across the University, other programs investigate the science of the global carbon cycle, the integrity of CO_2 storage in deep saline aquifers, and climate change policy.
Faculty: Dryer, Ju, Socolow

2.5 Vehicle Sciences and Applications

Vehicle design is central to the study of aerospace engineering. MAE faculty explore a variety of vehicle technologies and applications. These include underwater gliders for adaptive ocean sampling, autonomous micro-air vehicles, optimal aircraft and ship design using adjoint based methods, the Joint University Program for Air Transportation Research, satellite technology and orbital mechanics for astronomical and Earth science applications, hypersonic vehicles, advanced launch vehicles, and advanced propulsion technologies.
Faculty: Choueiri, Kasdin, Leonard, Littman, Martinelli, Miles, Stengel

2.6 Bioengineering

Bioengineering is a growing, multidisciplinary area, which applies methods and tools from engineering and the sciences to problems in biology and medicine. The research spans multiple length and time scales, ranging from molecules through cells to individual organisms and animal group dynamics. Current research activities include neuromechanics and hydrodynamics of swimming and legged locomotion; nanoparticles for cancer detection and treatment; cell mechanical properties and adhesion; the application of lasers for research in biomaterials and medical devices; biophysical and mechanical properties of lipid bilayers; modeling cognitive and neural mechanisms of decision and control; decision making and collective motion in animal groups; numerical simulation of steady and unsteady fluid flows in biological environments; and bioinformatic and biostatistical analysis of cancer.
Faculty: Haataja, Holmes, Leonard, Martin, Rowley, Smits, Soboyejo, Stengel, Suckewer

2.7 Fluid Mechanics

Experimental, analytical, and numerical studies of fluid flow underlie many areas of technological innovation. Turbulent flows, flow control, stability and transition, and the coupling with electromagnetic fields are areas of current interest. This area includes experimental studies of two- and three-dimensional supersonic and subsonic flows of varying complexity; boundary layer studies, especially turbulent boundary layers at subsonic, supersonic, and hypersonic speeds, over a wide range of Reynolds numbers; lowdimensional models and bifurcation analyses of turbulent and transition flows; active control of boundary layer turbulence and transition; new techniques in nonintrusive flow measurement; numerical techniques for solving the equations describing fluid flow, especially methods for calculating transonic flows over aircraft and reacting gasdynamics, and methods for calculating turbulent flows; fast iterative solutions; parallel algorithms; mesh generation; improved difference formulas; finite element and spectral methods; and aerodynamic shape optimization.
Faculty: Brown, Holmes, Martin, Martinelli, Nosenchuck, Smits

2.8 Lasers and Applied Physics

Lasers are important as diagnostic tools and in instruments whose use spans a spectrum from materials fabrication to medical applications. The underlying physics is applied to diverse areas

such as advanced propulsion systems, X-ray generation, and understanding the properties of complex materials and fluids. This area includes laser technology and applications; X-ray lasers; flow field and combustion diagnostics; multiphoton processes and nonlinear optics; high-energy lasers; atomic and molecular spectroscopy; molecular dynamics; plasmadynamics; high field phenomena; controlled laser-driven molecular and acoustic processes; picosecond and subpicosecond sources; high-energy incoherent source development; advanced spacecraft propulsion; space plasma physics; active space experiments; electric discharge; and radiation studies.
Faculty: Arnold, Choueiri, Littman, Miles, Scully, Suckewer

2.9 Materials and Mechanical Systems

Modern materials science seeks to understand and influence the behavior of materials at a variety of length scales, ranging from the atomic to the macroscopic, utilizing experimental and theoretical/computational tools as probes. MAE faculty are engaged in research that includes nanoscience, biomaterials, high-temperature materials, and laser-induced processing with diverse applications from medicine to alternative energy. For instance, magnetic nanoparticles are being designed for cancer detection and treatment; BioMEMS, artificial tissue, and orthopedic/dental structures are being constructed and explored; and bioinspired materials design is under way. Lasers are used to construct nanostructured materials for energy storage and power generation and are exploited in the field of adaptive optics and micromanipulation of materials with light. Quantum mechanics-based simulation tools are developed and used to explore and find ways to prevent oxidation, embrittlement, deformation, phase transitions, fracture, and mechanical wear of stressed and degraded metal alloys and ceramics at the macro and nano scale. Microstructural evolution in metals and in biophysical systems and biology are being examined with phase field approaches.
Faculty: Arnold, Carter, Haataja, Soboyejo

2.10 Multidisciplinary Programs.

Students may combine departmental courses and research with offerings by other departments or programs, as long as approved by the departmental Graduate Committee. This can be interdisciplinary programs developed by the student and advisor or come from one of the existing university programs such as the Program in Applied and Computational Mathematics, the Program in Atmospheric and Oceanic Sciences, the Princeton Environmental Institute, the Princeton Materials Institute, the Program in Plasma Physics, and the Program in Transportation among others.

3. Admissions, Registration, and Faculty Advisor

3. 1 Admission and Finding an Advisor

Admission to the Department is highly competitive. Normally, a student accepted for graduate work is expected to have met the requirements for a bachelor's degree in science or engineering and have had some exposure to independent research. The multidisciplinary nature of the departmental programs makes it unnecessary that this degree be in mechanical or aerospace engineering. Students with strong undergraduate training in physics, chemistry, mathematics, or another engineering field have been successful in pursuing graduate work in the Department.

It is normal for a particular professor or group of professors to indicate interest in working with the student at the time an admission offer is made. To facilitate first term advising, the Departmental Graduate Committee will appoint one of the interested faculty to act as an academic advisor.

The selection of a thesis advisor should be an early priority, and students are encouraged to consult with any faculty member about their choice of a thesis research topic. The Department will hold a Research Seminar Day and Faculty Research Lunch Seminars early in the fall semester during which students and faculty members will present brief talks about their research. It is hoped that this exposure will help entering students select a faculty thesis advisor, and permit them to become involved with a research program in their second semester. The Department will ask all first year students to identify their thesis advisor by the end of the first term. Fellowship students select faculty advisors by mutual consent.

It must be realized that each faculty member can only advise a limited number of students and the earlier the advisor can be identified the higher the probability of acceptance to the group. The faculty members in charge of particular research programs will advise the students who hold research assistantships with these programs. Most often, students will remain with a single research advisor throughout their graduate program.

3.1.1. Change of Advisors

Occasionally it happens that a student’s interests are no longer compatible with those of the original faculty advisor. In such a case, the student should see the Director of Graduate Studies to obtain assistance in clarifying whether a change of advisor would be useful. Although a change is better made sooner rather than later, it can occur as late as the time of passing the General Examination. Changes of advisor should never be made casually, but if it is clear that a change of advisor is required in order to pursue a different field of interest, then a direct approach is best. Of course, such a change must be discussed with the faculty member with whom you wish to become associated. That faculty member must be willing to accept you as a student and, unless you have outside fellowship support, be able to provide support. The current advisor **must** send a memorandum to the Director of Graduate Studies indicating agreement with the decision to change advisors. This change must be approved by the Departmental Graduate Committee.

3.2 Reenrollment

All Ph.D., MSE and part time MEng graduate students must apply formally for annual reenrollment. Reenrollment for MSE and Ph.D. candidates requires the written support of their advisor. The Departmental Faculty Graduate Committee considers all reenrollment applications for the following academic year in the spring term.

In order to be reenrolled to the second year of study with continuing Ph.D. candidacy, a student must satisfy the following departmental requirements: i) a course performance with an average of B or better, and ii) completion of the University English language requirement necessary for appointment as an Assistant-in-Instruction (see Section 3.3).

If a student is deficient in one or more of these areas, reenrollment to the second year of study may be granted on the basis of a strong recommendation from the student's advisor, but continuing Ph.D. candidacy will not be granted. During the second year, the student must concentrate on removing any deficiencies and is required to conduct an active research program. The research must be adequate to satisfy the requirement for an MSE thesis, and a written thesis draft must be presented to the student's advisor before reenrollment to a third year is considered, unless the deficiency is in the Language Requirement. If the deficiency is the University English Language requirement, and the student passes the POPT in the second year (see Section 3.3), then the student may be re-considered for Ph.D. status with a written statement from the advisor.

If the draft is judged to show strong research potential, and if all deficiencies have been removed, the student may be reenrolled for the third year as a Ph.D. student without the need to present the thesis to the Department. A student showing minimal improvement or still carrying a deficiency in one of the required components will be required to submit an MSE thesis and may be denied reenrollment for further study.

A MSE student must maintain a course performance with an average of B or better, and have a demonstrated proficiency in both written and spoken English, however, they are not required to pass the University English language test. Reenrollment requires the written support of their advisor.

The Dean of the Graduate School makes the final reenrollment decisions for all students, based upon the departmental recommendations. The Dean will notify all students of their reenrollment status.

3.3 English Language Requirement

Non-native English speakers who are accepted to the MAE Ph.D. program are required to demonstrate their English language proficiency. This can be done before enrolling at Princeton University by taking and passing the Test of Spoken English (TSE) with a score of 50 or higher. Alternatively, in the entering year, the student can take the Speaking Proficiency English Assessment Kit (SPEAK) test and pass with a score of 50 or higher. The SPEAK test is administered by the English Language Program (ELP) in September after academic classes have begun. Students who do not pass the TSE or SPEAK test are required to enroll in ELP classes and successfully pass the Princeton Oral Proficiency Test (POPT). Any student who does not pass TSE, SPEAK or POPT before the end of their first year of study cannot stand for their general exam or serve as an Assistant-in-Instruction, and therefore will not be reenrolled as a

Ph.D. student. A student in this category who is recommended for reenrollment for his/her second year will be reenrolled as an MSE candidate. Ph.D. candidacy may be reconsidered upon successful completion of the POPT.

3.4 Registration

All students are required to register, in person, in September on the date specified by the Graduate School. Also at that time, students must register through SCORE for courses. All first year students are required to submit to the Graduate Office a signed (by advisor) course selection worksheet. Registration for the spring term is accomplished by completing course registration through SCORE and submitting signed worksheets.

3.4.1. Changing Degree Programs

New graduate students are accepted as Ph.D., MSE or MEng candidates in accordance with their indicated interest on the application form. The degree program can be changed from MSE to Ph.D., or vice versa, with the approval of the MAE Graduate Committee. A change from MEng to MSE or Ph.D. requires application. A change from MSE or Ph.D. to MEng is not permitted.

4. The Ph.D., MSE, and the MEng Programs

All graduate degree programs draw on the same selection of courses and the performance expectations are the same for all degree candidates. To remain in good standing, Ph.D. and MSE and MEng students must maintain a “B” average in their courses. The degree requirements comply with the regulations of the Graduate School concerning admissions, residence, program structure, and time to completion of the degree.

4.1 The Ph.D. Program

The Ph.D. program is typically of 5 years duration. Formally, a Ph.D. student must complete one year of full-time residence (meaning that a student is present on campus using University resources to fulfill degree requirements and objectives a majority of days per week for the academic term or year), pass the General Examination, and submit an acceptable dissertation to the department. The Ph.D. program is designed to prepare a student for a career in basic research and teaching, and candidates are expected to demonstrate strong scholarly abilities and the capacity for independent thought.

In consultation with a faculty advisor, a Ph.D. candidate develops an integrated program of courses and research in preparation for the General Examination. Although there are no formal course requirements for the degree, each candidate is expected to demonstrate competence in certain core subjects to the satisfaction of the department as a whole. The basic topics vary for individual programs, but must include applied mathematics and at least two areas of departmental/interdisciplinary concentration. Approved courses from other departments may be offered, and members of these departments may be invited to participate in the General Examination. The first three terms are spent taking courses (at least eight), taking pre-Generals interviews, and performing preliminary research in preparation for passing of the General Examination, which is normally taken in January and May of the second year. The balance of the program is spent on dissertation research, teaching obligations, and additional courses. All Ph.D. candidates are normally required to serve as Assistants-in-Instruction for the equivalent of three semester courses. (See Section 4.1.7). The culmination of the Ph.D. program is the writing of a thesis on a research topic explored by the student and a presentation of this work in a Final Public Oral examination.

4.1.1 Requirements for the Ph.D. Degree

The University imposes no course requirements on Ph.D. candidates; however, the Departmental General Examination uses the scope of certain courses to define the subject areas. Section 6 lists departmental graduate course descriptions. The course of study and research should be selected so that the Ph.D. program can be completed in no more than five years.

Departmental students are required to take eight courses for credit prior to standing for the General Examination. First-year students normally take seven approved courses for credit during the first year. Taking at least seven courses in the first year permits a student to concentrate on pre-generals interviews and research in the fall term of the second year. Students are also required to be an Assistant-In-Instruction (AI) for at least 3 courses upon passing of his/her General Exam.

4.1.2 Qualifications and Ph.D. Candidacy

The decision to pursue a Ph.D. or MSE course of study should be made as soon as possible but no later than the beginning of the third semester. By that time, all Ph.D. students must have submitted their Request for General Exam for approval by the MAE Graduate Committee. This form includes the public presentation research topic, the subject areas to be defended in the General Examination, the planned Pre-Generals interviews, and the anticipated date, topics, and examiners for the Ph.D. General Examination. This form also asks for the signatures of the student's advisory committee.

4.1.3 Advisory Committee for Ph.D. Candidates

Prior to the beginning of the third semester of the second year, the faculty advisor, in consultation with the student, shall have appointed a Ph.D. advisory committee for the student. The Advisory Committee is chaired by the student's thesis advisor and has two other members. At least one member should be a faculty member with competence relevant to the student's program of study and may be from any department of this University. One member of the committee may be a research staff member with a continuing appointment. If a desired member of the committee is not associated with Princeton University, approval must first be requested from the MAE Graduate Committee.

The main duties of the Advisory Committee members are to interact with the student and to render assistance in pursuit of the academic and thesis research program. It is the student's responsibility to keep the committee members informed about their research activities, and to arrange discussion time. The advisory committee members will also serve as examiners for the Research Component of the student's General Examination. This committee is distinct, however, from the faculty group who will act as examiners in the Subject Component of the General Examination.

4.1.4 The General Examination

The Ph.D. degree in MAE is a certification that the graduating student is well versed in the fundamentals of his or her chosen field and is capable of performing creative, independent research and of effectively communicating that work to both a technically sophisticated and a lay audience. The general examination procedure exercises the Department's responsibility for determining a student's potential to satisfactorily complete a Ph.D. and simultaneously encourages the student to review and consolidate material from various courses and research activities. The general examination procedure in MAE thus has four goals:

1. To motivate the student to review and synthesize course work and research material.
2. To determine the creative potential of the student to conduct Ph.D.-level research.
3. To determine the student's ability to understand and apply fundamental concepts.
4. To develop and test the student's ability to communicate materials orally and respond to questions and comments.

The general examination process consists of three components: i) three pre-general interviews completed during the Fall of second year, at least one of which is in mathematics, ii) an oral examination taken in January of the second year (the "subject component") in four areas chosen by the student (one of which must be mathematics, two in a major area, and one in a minor area), and iii) a 45-minute presentation (the "research component") followed by questions, normally in May of the second year, on a topic related to the student's planned Ph.D. program. Additionally, prior to taking the general examination, all students are expected to demonstrate competence in their course work through a GPA of 3.0 or higher. Students indicate their desire to stand for the general exam by submitting the "General Exam Request From" to the department's graduate office no later than the start of Winter break of their second year.

Finally, all candidates for the Ph.D. degree are expected to be competent in both written and spoken English. Many departmental examinations and, in particular, the pre-general interviews and the general examination, are oral and students who do not speak English well are at a disadvantage. Students who feel that they need help in improving their English skills should consult the MAE graduate office for advice about courses. English language competency is demonstrated through successfully passing the POPT exam or by receiving a score of 50 or higher on the SPEAK. See Section 3.3 for details on the Department’s English Language Requirement.

The remainder of this section describes the requirements and expectations for each element of the general examination process. The student must successfully pass both the subject component and the research component to proceed with a Ph.D. A successful student will complete both of these components by May of the second year. The various failure scenarios are described at the end of this document. The following is a typical general exam schedule; exceptions to this schedule are made only by petition and approval of the graduate committee.

4.1.4a General Examination Schedule

- July and August – a combination of studying for the subject components and interviews and concentration on research.
- September – completion of first interview
- October – completion of second interview
- November – completion of third interview
- December – submittal of General Exam Request Form
- January – subject component of general exam
- May – research component of general exam

4.1.4b Pre-Generals Coursework

Students are expected to take eight courses for a grade during the first three semesters prior to standing for the general examination. These courses provide the foundation of material for the subject component of the exam. Of the required eight courses, two must be in mathematics, at least three must be in the primary area of research, and at least two in another secondary area of interest. The student may select the secondary area from inside or outside the department, but should discuss the choice with his/her advisor. Normally the secondary area is related to the student's planned Ph.D. research, but it is not required to be so. It is also required that one examiner in the subject component of the general exam is from the student's secondary area. Students must achieve an average grade of 3.0 or higher in these courses to stand for the general exam. Approval of the primary and secondary area, and qualification for taking the general exam, is made by the graduate committee based upon information supplied on the "General Exam Request Form".

4.1.4c Pre-General Interviews

Before a candidate stands for the General Examination, individual interviews will be taken with at least three faculty members or research staff (selected by the student in concert with the advisor) and approved by the graduate committee The list of available interviewers and their subjects is attached. These interviews are intended to explore, in-depth, the student's knowledge of a subject area, to prepare the student for the General Examination, and to identify areas where further study may be necessary. There is no requirement to pass or fail an interview; interviews are for the benefit of the student to ensure adequate preparation for the subject component of the general exam. In some cases of weaker performance, interviewers may request additional time from the student after further studying.

Written work may be a part of the interview, but the practice has been for each interviewer to conduct one or more oral sessions extending over several hours. Students are advised to begin their interviews early, even as early as the end of summer prior to their third semester. It is helpful to schedule about one interview per month. One interview must be taken in Math; other interviews are left up to the discretion of the student and their advisor.

The MAE Graduate Office maintains a list of faculty who are available to give interviews in the various subject areas. In order to give the student the widest possible exposure to the faculty, the particular faculty member chosen to give an interview in a selected area must not be one of those who taught the student in that area. Exceptions to this rule can be made only with the prior approval of the MAE Graduate Committee. Normally, interviewers and course instructors should not be used as an examiner in the general examination. In the event that an adequate number of faculty is not available, it is preferred to use a course instructor, rather than the interviewer or advisor, as an examiner. Students are always free to seek additional guidance in preparation for the general examination from their Ph.D. advisory committee or any faculty member.

At the completion of each interview, the interviewer submits a signed Pre-General Interview Data Form to the Graduate Office with a written performance evaluation. This document is made available to the student. Students are encouraged to review the form carefully as it provides valuable feedback on their preparation for the subject component. **All interviews must be completed prior to the December winter break when the General Exam Request Form is due.**

4.1.4d Subject Component

The subject component of the general examination is designed to ascertain the student's general knowledge and reasoning capability in subjects relevant to the chosen program. It is designed to comprehensively address the material from the students undergraduate and graduate course work. However, the subject component is not intended to be a summary exam on the graduate course material but rather is an opportunity for the student to demonstrate an ability to synthesize the material from his or her courses and answer unfamiliar questions. The first year course of study should provide an adequate outline of the material needed to succeed in the subject component of the general exam.

The Subject Component is a two-hour oral examination chaired by a member of the Graduate Committee who is neither the student’s advisor nor an examiner. Faculty members of other departments in the University may be invited to participate in the areas of their expertise, particularly for the secondary area. The Subject Component consists of four parts, each one-half hour long, as follows: one part devoted to math, two parts devoted to the major area (with two different examiners) and one part devoted to the secondary area. The student is expected to be conversant in the following applied math topics, all covered in MAE 501, 502:

1. Differential Equations: a) Ordinary Differential Equations, (b) Partial Differential Equations, (c) Special Functions and Boundary Value Problems, (d) Laplace Transforms
2. Linear Analysis: (a) Vector Analysis and Cartesian Tensors, (b) Matrices and Linear Equations
3. Advanced Calculus: (a) Multi-Dimensional Calculus, (b) Variational Calculus, (c) Complex Variables
4. Fourier Analysis: (a) Series, (b) Transforms, (c) Orthogonal Functions
5. Numerical Analysis

Immediately following the examination, the examiners, graduate committee chair, and faculty advisor convene to decide whether or not the student has sustained the subject component. The student is notified after a decision is made.

The student, together with the advisor, selects 3 examiners for the math, major and minor components (a total of 9 possible examiners). The Graduate Office will randomly choose the four examiners from this list. Interviewers and the advisor should not be selected as examiners. Course instructors should only be used as examiners if necessary. The graduate office will take responsibility for scheduling the Subject Component for each student.

4.4.4e Research Component

The research component of the general exam consists of a 45-minute-long public seminar followed by questioning from the faculty and others present. The faculty attendees include the student's Ph.D. Advisory Committee (the student's advisor and two other members with competence relevant to the student's program of study) and a representative from the MAE Graduate Committee. Any substitution for a member of the Ph.D. Advisory Committee must be approved in advance by the Graduate Committee. The student will be asked to provide an extended abstract to the Graduate Office for submission to the entire MAE faculty, the Ph.D. Advisory Committee, and any other examiners two weeks prior to the examination. The role of the examiners is to assess the ability of the candidate to carry out scholarly research. A successful research component will be one in which the student demonstrates the ability to do independent research and to organize and communicate technical material and ideas to a relatively general audience. The candidate should demonstrate: 1) an extensive knowledge of the literature in his/her field of research, 2) the ability to plan, organize and initiate an independent research project and 3) the ability to integrate relevant areas of study into the research. Students are not evaluated on original contributions or advancements of knowledge; that is the purpose of the Ph.D.

4.1.4f Failure Scenarios

While the majority of students pass the general examination on their first attempt, it is the case that some do not. It is university and department policy that students be given two attempts to successfully pass the examination. The following are the various possible failure scenarios a student may encounter:

1. Fail Subject Component in January – A student who fails the Subject Component for the first time in January of the second year will be given a second (and final) opportunity to retake the subject component in May of the second year. Upon passing the subject exam in May, the student has the option to take the research component in October of the third year, but is encouraged to take it during the same May exam period in order not to unnecessarily extend the time to degree.

2. Fail Subject Component in January and in May – A student who fails the subject component again in May will be given the option to complete an MSE thesis and degree. It is expected that the level of research at this point would be such that the student could likely complete the MSE degree by the end of the summer following the second year.

3. Pass Subject Component but Perform Poorly on First Try at Research Component – There are three possibilities for a student who passes the subject component in January (in May) but performs poorly on the first try at the research component in May (in October). The faculty committee members attending the research component make the decision based on their assessment of the student's performance, record and capabilities. One possibility is that the faculty committee gives the student a "Fail" on the research component but recommends that the student retake the research component in October (in January) of the third year. A second possibility is that the committee gives the student a "Fail" on the research component and recommends that the student complete an MSE thesis and degree. Finally, the committee can give the student a "Terminal Pass" which means the student leaves with an M.A. degree.

4. Poor Performance on Second Try at Research Component - In the event that the student performs poorly on the research component on the second try, then the student can be given a "Fail" or a "Terminal Pass". The former would make it possible for the student to stay and complete an MSE degree and the latter would require the student to leave with an M.A.

4.1.5 The Master of Arts Degree

A student who passes the General Examination is automatically eligible to receive the M.A. (Master of Arts) degree. It is necessary to apply for this degree by completing the Degree Application Form, which may be obtained from the MAE Graduate Office. Application for this degree can be made any time after the student passes the General Examination.

4.1.6 Post-Generals Courses

Post-generals students will be required to take a minimum of 2 additional courses, at their leisure, so that the total number of courses taken for credit is at least 10. Further, these two courses can be taken for a grade or as P/F. This is independent of the three-course AI requirement. All students are strongly encouraged to continue taking courses beyond the 10 course requirement. Students are also encouraged to try courses in areas other than those of their specialization to broaden their education. It is understood that all courses will be selected in consultation with the faculty advisor.

4.1.7 Assistant-In-Instruction

It is a requirement for students to AI three (3) half time AI assignments in order to qualify for their Ph.D.. The Graduate office will arrange all AI assignments based on department courses offered and department need, along with the students available to AI. This office will also assess what kind of AI work is needed. We will accommodate requests for particular assignments when possible. The final assignments will be made by the Director of Graduate Studies. Based on Graduate School policy, the appointment of half time assignments will require approximately 9-10 hours of work for the AI assignment per week. This will allow you to maintain some research projects during the semester.

4.1.7a AI Responsibilities

Assistants-in-Instruction are a vital component of the overall teaching effort of the University. AIs assist faculty in the instructional program of the course in many ways. It is important to have a clear idea of your AI responsibilities at the outset of the term. The professor in charge of the course will assign specific duties and you should make an appointment with him/her prior to the onset of the semester. However, some of the responsibilities you may be required to do are listed below:

- Attend lectures – being present at lectures will confirm what you need to know for each lecture and will let the students know you are available
- Leading Precepts or Conducting Problem & Study Sessions – typically a weekly meeting meant to supplement the course lecture and provide students with an opportunity to openly discuss the subject matter in a small group. As preceptor you will be responsible in assisting the students to grasp/master the concepts discussed in the course. To gain this the precepts are typically structured to clarify lectures, review problem sets and prepare for examinations, etc. This aspect of AI may require discussions with the course head on deciding priorities and strategies to assist in teaching.
- Supervising Laboratory Sections – assist students in understanding the labs and integrating the lab exercises with the lecture material. With the assistance of the Lab Research staff, set up for experiments and prepare yourself in advance for the lab.
- Grading – in many cases this is the primary responsibility for AIs and can be a full time job in and of itself. You should meet with the course head to determine the methods of grading and keep precise records of grades. Because it can be so time consuming, please plan ahead to prepare yourself for the grading of midterms and finals.
- Prepare Course Materials and Examinations – copying, etc. Please see Graduate or Undergraduate Administrator for the code to make copies and/or order desk copies. Please do not order books without discussing this with the Undergraduate Administrator.
- Meetings – attend all meetings with additional AI members and/or faculty member.

4.1.7b AI Guidelines:

AI assignments, even half time or less, can be very time consuming. University guidelines are based on at least 2 hours of preparation for each hour of classroom contact per week. An AI assignment of “3 hours” (or half time) should take the three hours of class meeting plus an additional 6-7 hours of work, therefore approximately 10 hours per week. Although this is a guideline it is not a rule and not set in stone. The requirements of each course vary. It is important that you discuss this with the faculty member in charge of the course. Reading period, examination periods, and grading periods are considered to be a part of the semester and you should schedule to be available for students and faculty during those times.

There are two Princeton University tools available to you. First is the McGraw Center for Teaching and Learning. The center holds an annual Teaching & Orientation Conference in the Fall for all new and experienced AIs. It is typically a two day conference in early September and all AIs will be required to attend. Secondly there is a Princeton University AI manual available on line at: http://www.princeton.edu/~aiteachs/handbook/index.html.

4.1.8 The Ph.D. Dissertation

A Ph.D. dissertation may be presented for official action only by students who have sustained the General Examination. The dissertation submitted to the Department and to the Graduate School must be a scholarly and coherent report of the work performed by the candidate, and must be written in English. The dissertation, which can only have a single author, must show the candidate's mastery of a defined field and demonstrate the capability for independent research. This research must disclose new principles or facts, enlarge or modify what was previously known, or present a significant new interpretation of the subject. In particular, the dissertation must clearly identify the significance of the results obtained, and must contain material of publishable quality. A simple gathering of previously published or co-authored papers does not constitute a Ph.D. dissertation and will not be accepted. Proper citations of joint work must always be given, and the specific contributions of the author of the dissertation must be clearly identified.

A student is normally expected to conduct research for the Ph.D. dissertation while in residence. The Department discourages dissertations written in absentia except under special circumstances such as the need to use facilities not available at Princeton. Students who plan to complete dissertations in absentia should notify the MAE Graduate Committee as soon as possible. A research plan, accompanied by written approval of the student's advisor and Ph.D. advisory committee, should be submitted to this Faculty committee before leaving Princeton. The student is required to stay in close contact with the Graduate Office.

According to the Graduate School, Ph.D. degree candidacy terminates five years after the date of passing the General Examination. If a student presents a dissertation for the Ph.D. degree more than five years after passing the General Examination, the Department is not obligated to receive it. Students anticipating a delay in presenting the final dissertation should keep the Department informed, so that their progress can be appropriately monitored. The Faculty is permitted to vote to receive a dissertation that is submitted later than the five-year limit.

Two principal readers of the Ph.D. dissertation are appointed by the faculty advisor after consultation with the candidate. At least one reader must be an active member of the Department with the rank of assistant professor or higher. The other reader may be a faculty member at Princeton or another university with the rank of assistant professor or higher who has a demonstrable expertise in the student's area of study. A research staff member with a continuing appointment may be a second reader (provided the first reader is a Princeton faculty member) but not for a student within the staff member’s own research group. The suitability of a reader from industry, government, or another university should be checked with the Director of

Graduate Studies. A current vitae for an outside reader is also required at the time the dissertation is delivered to the MAE Graduate Office.

The student should notify the Graduate Office when a final draft of the completed dissertation and Reader's Report Forms have been submitted to the advisor and to the readers. The student is expected to have received preliminary comments from the readers prior to the final copy being approved by the advisor. The readers will submit Reader's Reports within a four-week period of receiving the final thesis. The student should notify the Graduate Office if a response from the advisor and/or readers is not made within this time.

When the advisor's and the two readers' reports on the Ph.D. dissertation are favorable, the final version of the dissertation should be prepared. The thesis text must be double-spaced and appear on only one side of the page -- not back-to-back. Full information about the required format can be found at: http://www.princeton.edu/~mudd/thesis/requirements.pdf. The abstract, in 12-point type, may not exceed 350 words and must be double-spaced. The dissertation must carry a T number, which may be obtained from the MAE Graduate Office. This number should be noted as the last paragraph under Acknowledgments and should read: "This dissertation carries the number T-#### in the records of the Department of Mechanical and Aerospace Engineering."

Two hardbound copies of the dissertation on good quality, acid-free paper shall be submitted to the MAE Graduate Studies Office for reading by the faculty. These copies will be kept for two weeks in the MAE Graduate Office. They are also the copies that will go to Mudd Library upon successful completion of the Final Public Oral. They are to have a signature page with the advisor, author and readers signatures. At the same time, copies of the dissertation shall also be given to the two designated examiners for the Final Public Oral Examination. The student's faculty advisor must prepare a memorandum announcing that the student's dissertation is available for reading to be submitted along with the Reader's Reports to the Department faculty. A sample memo can be obtained from the Graduate Office. At least two weeks must elapse between the submission of the two hardbound copies to the MAE Graduate Office and the date of the Final Public Oral Examination.

Although it is expected that students will normally satisfy their advisor as to the quality of their thesis research and written presentation, situations may arise when there is an irreconcilable difference of opinion about the quality of the work. In such a situation, the student may request that the Departmental Graduate Committee appoint two principal readers, both normally members of the Princeton University faculty with the rank of Assistant Professor or higher. After reviewing the advisor's comments on the thesis, the Committee would select the two additional Readers and transmit the thesis to them together with the comments of the advisor. Upon receipt of the Readers' written and signed reports the Graduate Committee will review these and the Advisor's report. If two or more of these reports state that the thesis is not of Ph.D. caliber, the Graduate Committee will notify the candidate that the department has terminated the process and that the student fails to meet the requirements for the Ph. D. degree. If at least two of the three reports recommend positive action on the thesis, two copies of the thesis will be placed on display in the Graduate Office. The faculty will be notified of this and sent copies of all three reports. A two-week period will be allowed for faculty comments on the thesis, after which the Graduate Committee will arrange for the Final Public Oral examination, provided the student has paid graduation and publication fees.

At the time the approved copies of the dissertation are submitted to the MAE Graduate Office, the candidate must complete the Degree Application Form and the Termination Form, which are obtained from the MAE Graduate Office. The student should review the Ph.D. Checklist to see all that is required and when it should be submitted. At the same time the student's advisor will complete the Ph.D. Dissertation Report form.

Ph.D. degrees are awarded at five times during the academic year. These times correspond to the September, November, January, April and June meetings of the Board of Trustees, which are listed on the Degree Application Form. The two hardbound copies of the dissertation must be submitted to the MAE Graduate Office at least seven weeks prior to any meeting date of the Board of Trustees in order for the degree to be granted at that particular time.

4.1.9 The Final Public Oral Examination

Permission to hold the Final Public Oral Examination will be given only after the Degree Application, the Termination Form, the Ph.D. Dissertation Report Form, two (2) signed hard-bound copies of the dissertation, two readers' reports, and the faculty memo have been submitted to the Graduate Office for transmittal to the Graduate School. After permission to hold the Final Public Oral Examination is granted, the graduate office will distribute to the faculty the memo and announcement of the Examination.

Immediately before or after the Final Public Oral Examination, the student is required to complete two copies of the Survey of Earned Doctorates Form, which will be provided by the Graduate School, and the Departmental Exit Form.

The Final Public Oral Examination is in three consecutive parts:

(a) A lecture of about 45 minutes by the candidate on his or her research. Faculty, students, and the public are invited to attend.

(b) Questions by the designated examiners.

(c) Questions by other faculty and attendees after the lecture.

The Examination is not limited to a defense of the student's dissertation. Questions that test the general knowledge of related subject matter may be raised.

In addition to the advisor, there must be at least two principal examiners for the Final Public Oral Examination, normally active members of the Princeton University faculty with the rank of Assistant Professor or above. At least two of the examiners must be distinct from the principal readers of the dissertation; they should be provided copies of the dissertation at least two weeks prior to the date of the Final Public Oral Examination.

After the Final Public Oral examination, the Graduate Committee will hold a formal meeting to which all faculty are invited. At this meeting, the final decision to recommend the granting of the Ph.D. will be based on the student's performance in the Final Public Oral examination, and the comments of the Readers and the Advisor. This recommendation will be transmitted to the Dean of the Graduate School.

4.2 Master of Science in Engineering (MSE) Program

The Master of Science in Engineering program is of two years duration and is designed for a career in industrial, non-government organizations, or government research and development. MSE candidates are required to take at least seven courses in addition to writing a thesis, which demonstrates their mastery of selected technical areas.

4.2.1 Requirements for the MSE Degree

To qualify for the M.S.E degree, each student must be in residence for one year (meaning that a student is present on campus using University resources to fulfill degree requirements and objectives a majority of days per week for the academic term or year), perform at a “B” average level or better in a minimum of seven courses selected in consultation with the faculty advisor, and submit an acceptable thesis. If only seven courses are taken they are to be completed in the first year. The MAE Graduate Committee must approve all programs. A thesis is required of each Master's candidate and is the culmination of his/her program of research conducted under the supervision of a faculty advisor.

Candidates with a grade average lower than “B” at the end of the first semester will be warned of the need for improved performance to meet the degree requirements. For reenrollment to the second year, the average of the first year course grades must be no lower than a “B”. Normally, only one course with a grade of “C” will be counted as part of the required seven for the degree.

4.2.2 The Master's Thesis

After the research project is substantially completed, a draft of the thesis should be submitted to the student’s faculty advisor and at least one other reader selected by the advisor in consultation with the candidate. The reader should be chosen from the Princeton University faculty, have expertise in the student's area of study, and hold the rank of assistant professor or higher. Readers may also be faculty members at another university (with equivalent rank) or a member of the MAE Department's research staff with a continuing appointment. The staff member may not be selected from within the student’s own research group. Any uncertainties about the suitability of a reader from industry or from another university should be checked with the Director of Graduate Studies. When an outside reader is used, a vita is also required and must be submitted at the time the thesis is delivered to the MAE Graduate Office. The suggestions of both the advisor and the reader shall be considered, and their approval secured, before submission of the final bound copies of the thesis to the Department.

The student must notify the Graduate Studies Office when a draft of the completed thesis is submitted to the advisor and to the reader. A form requesting that the thesis be read will be issued, and the student should be informed of any required changes within a four-week period. The student is expected to receive and act upon these comments prior to the final copy of the Thesis being approved by the advisor. The student should notify the Graduate Studies Office if a response from the advisor or the reader is not made within this time limitation.

Two hard-bound copies of the thesis on good quality, acid-free paper must be submitted to the MAE Graduate Studies Office for reading by the Departmental faculty. The availability of the thesis for reading by the faculty will be announced promptly in a memorandum from the advisor, which will also include the reader's report. If other faculty members raise no objections within

the required period of one week, the Department will then formally approve the thesis and recommend it to the Dean of the Graduate School. The thesis must carry a T-number, which can be obtained from the MAE Graduate Office. The last paragraph under Acknowledgments shall read: "This thesis carries the number T-#### in the records of the Department of Mechanical and Aerospace Engineering." Xerographic reproductions on acid free paper are acceptable. Information about the required format for the thesis may be found at:
http://www.princeton.edu/~mudd/disserta.html

The Degree Application form and Termination form must be submitted to the MAE Graduate Studies Office before the student is recommended for the MSE degree. They must be filled out electronically and can be found in the graduate office and on the web. Master's degrees are awarded three times during the academic year. These times correspond to the November, January, and May meetings of the Board of Trustees, and are listed on the Degree Application form. Two hardbound copies of the thesis must be submitted to the MAE Graduate Studies Office ***at least seven weeks prior*** to any of the meeting dates of the Board of Trustees in order for the degree to be granted at that particular time. A copy of the thesis should then be taken to Mudd Library. The student should review the MSE Checklist found in the graduate office and on the web.

A student is normally expected to complete research for an MSE thesis while in residence. The Department discourages theses being written in absentia, except under special circumstances–e.g., the need to use facilities not available at Princeton. Students anticipating the need to complete a thesis in absentia should notify the Graduate Committee as soon as possible, and this notification should be accompanied by written support from the student's advisor. If this proposal is approved, an agreed research plan must be prepared in conjunction with the advisor, and an annual progress report must be sent to the Graduate Committee. If a thesis is not submitted within five years after a student leaves the University, degree candidacy will be discontinued and the faculty will no longer be obliged to consider any document submitted.

4.3 Master of Engineering (MEng) Program

The MEng Program is particularly suited to those interested in either obtaining a more fundamental understanding of their field or in broadening their experiences to include disciplines outside of their particular technical focus areas.

4.3.1 Requirements for the MEng Degree

The M.Eng. program may be satisfied by taking eight (8) graduate courses; six of which must be in technical areas with no more than two being independent projects. The balance of the courses should be selected to provide a coherent exploration of a supporting area. Students are encouraged to develop a curriculum together with their faculty advisor. A minimum of four courses must be taken in the Department, and the remaining four courses can be chosen freely, so long as a coherent program is developed. Undergraduate courses cannot be taken without prior approval of the Graduate Committee, with the exception of those courses that have been previously approved as part of the Departmental core programs. To qualify for the MEng degree, the eight courses must be passed with at least a “B” average. No more than one “C” grade will be permitted to count towards the eight courses.

The degree does not require a thesis. Typically, the MEng program requires nine to twelve months in residence (meaning that a student is present on campus using University resources to fulfill degree requirements and objectives a majority of days per week for the academic term or year), and is awarded on the basis of course performance. Part-time participation is a possible option.

4.3.2 Programs of Study

The M. Eng. degree program attempts to make individual programs as unconstrained as possible. Opportunities for study exist in the following areas: Combustion and Propulsion; Computational Mechanics; Control and Dynamic Systems; Energy and Environment; Fluid Mechanics and Computational Methods; Laser-Matter Interactions; Materials, Structures and Design; Optical Measurements and Instrumentation; and Space Propulsion. If an MEng student is interested in a particular course that is not being offered during his or her year of study, it may be possible for a faculty member to offer the course as a "Reading Course." If so, course approval must be obtained from the MAE Graduate Committee.

The Department offers three types of MEng programs. The degree can be taken with technical courses concentrated in one of the "Topical Areas" of Departmental research. The program, "Expanding Your Horizons in Mechanical and Aerospace Engineering," provides a unique opportunity for students interested in broadening their experiences to include disciplines outside of their particular technical focus areas. Princeton University is world-renowned not only in engineering but in other areas related to engineering practice. Students entering this program will have the opportunity to take advantage of these Princeton strengths. A special option for Princeton students, "The Princeton Option", permits enrolled undergraduate students to follow a five-year program leading to the award of both a B.S.E. degree and the Masters of Engineering. Interest in this option should be indicated in the Junior year, and a completed application should be submitted to the Graduate School by May 1st of that year.

5. Miscellaneous

5.1 Graduate Student Committee

The Graduate Student Committee is organized in accordance with the University's "Rights, Rules, and Responsibilities." This Committee represent the interests of the graduate student body of the Department. The graduate students elect the Officers of the Graduate Student Committee. In addition to a variety of social and academic activities, the committee meets regularly to discuss and act upon issues that affect the graduate students. The Faculty Graduate Committee frequently solicits the opinions of the Graduate Student Committee and uses it as a sounding board for pending policy issues. A formal meeting between the Student committee and the Director of Graduate Studies is required each term at a mutually agreeable time.

5.2 MAE Graduate Student Vacation Policy

Departmental vacation policy is consistent with the Graduate School guidelines which state: "Regardless of the source of students' financial support, graduate students are expected to work essentially full time fulfilling degree requirements. Graduate students therefore accrue no specific vacation time **other** than the normal short holiday periods observed by the University, such as winter recess, spring break, and the inter-term period.

5.3 Office Space, Keys to Laboratories, Mailbox

Students will be assigned office desk space. Any questions should be directed to the MAE Graduate Office. Whenever possible the student's office will be in reasonable proximity to that of the faculty advisor. When the student arrives he/she will have a mailbox in the MAE Mail/Copy Room. Laboratory keys can be obtained in the MAE Department Office (D212).

5.4 Weekly Bulletins

The University publishes a weekly announcement of scheduled lectures, concerts, sports events, etc. on the web. MAE posts a weekly bulletin to all MAE email accounts.

A weekly Departmental bulletin describing events of special interest to the Department is posted on the graduate student bulletin boards next to D228. These boards maintain calendar of events, course information, conference information, fellowships and awards, and job postings.

5.5 University Prizes and Fellowships

Each September the MAE Department honors the top students who have just completed their first year by awarding the Sayre Graduate Prize(s). This is a cash prize. The Luigi Crocco Prize is awarded to an outstanding Assistant-in-Instruction from the prior year and is also a cash prize. The Larrise Rosentweig Klein Prize recognizes a women student in the third year, or beyond who has shown exemplary research capability. The department offers 5 second year fellowships to students who have been chosen as showing exemplary work in both studies and research in their first year and 1 Post Generals Fellowship to a student who excels in both research and academics. The Graduate School offers Honorific Fellowships, and the Department nominates a top student entering the final dissertation year for this award.

5.6 Outside Fellowships

MAE encourages students to apply for outside fellowships. The Graduate Office will provide a list of known fellowship opportunities each September. Students awarded an external fellowship will receive a prize allowance. To encourage the applications to outside fellowships, a $50 award is given for each fellowship application submitted.

6 Departmental Graduate Courses

501/APC 501 Mathematical Methods of Engineering Analysis I

Methods of mathematical analysis for the solution of problems in physics and engineering. Topics include an introduction to functional analysis, Sturm-Liouville theory, Green's functions for the solution of ordinary differential equations and Poisson's equation, and the calculus of variations.

502 Mathematical Methods of Engineering Analysis II

An extension of MAE 501. A complementary presentation of theory, analytical methods, and numerical methods. The objective is to impart a set of capabilities commonly used in the research areas represented in the Department. Standard computational packages will be made available in the courses, and assignments will be designed to use them.

503/APC 504 Basic Numerical Methods for Ordinary and Partial Differential Equations

Difference schemes for ordinary differential equations; analysis of simple difference schemes for model hyperbolic and parabolic problems; the linear advection condition; explicit and implicit schemes; difference and interpolation formulas on equal and unequal meshes with error estimates; Lagrange interpolation: Peano error estimates; least squares approximation: orthogonal polynomials' piecewise polynomial interpolation: splines; trigonometric interpolation and error estimate for spectral approximation; Chebyshev expansions; numerical quadrature; iterative solution of nonlinear equations; and inversion of sparse sets of equations.

509, 510 Advanced Topics in Engineering Mathematics I, II

Selected topics in mathematical methods, with an emphasis on advances relevant to research activities represented in the department. Possible topics include analytical methods for differential equations, numerical solution of hyperbolic equations, and statistical methods.

511 Experimental Methods: Introduction to Electronics for Engineering and Science

A laboratory course that focuses on basic electronics techniques, digital electronics, and data acquisition and analysis. Topics include introduction to digital and analog electronics, digital-to-analog and analog-to-digital conversion, microcomputer sampling, and data analysis. There are four laboratory hours and two lecture hours per week. There is one project. Enrollment is limited.

512 Experimental Methods II

An exploration of experimental techniques in fluid mechanics and combustion. The course introduces experimentation, error analysis, and technical communication. Methods covered include pressure and temperature probes, flow visualization, hot-wire and laser anemometry, line reversal, Raman techniques, fluorescence, absorption, gas chromatography, and mass spectroscopy. There are three lecture hours and laboratory time per week.

513, 514 Master of Engineering Independent Project I, II

Directed study for Master of Engineering students. The topic is proposed by the student and must be approved by the student's research advisor and received approval from the MAE Graduate Committee.

515 Extramural Summer Project

A summer research project designed in conjunction with the student's advisor and an industrial, NGO, or government sponsor that will provide practical experience relevant to the student's thesis topic.

519, 520 Advanced Topics in Experimental Methods I, II

Selected topics in experimental methods, with an emphasis on advances relevant to research activities represented in the department. Possible topics include dynamic data analysis; instrumentation and systems analysis, scanning probe techniques, and nanoscale materials property measurements.

521 Optics and Lasers

An introduction to principles of lasers. Topics include a review of propagation theory, interaction of light and matter, Fourier optics, a survey and description of operational characteristics of lasers, light scattering, and nonlinear optics. Some introductory quantum mechanics will be covered to give students an appreciation of the basic tools for the interaction of light with matter and nonlinear optical phenomena.

522/AST564 Applications of Quantum Mechanics to Spectroscopy and Lasers

An intermediate-level course in applications of quantum mechanics to modern spectroscopy. The course begins with an introduction to quantum mechanics as a "tool" for atomic and molecular spectroscopy, followed by a study of atomic and molecular spectra, radiative, and collisional transitions, with the final chapters dedicated to plasma and flame spectroscopic and laser diagnostics. Prerequisite: one semester of quantum mechanics. (Offered in alternate years)

523 Electric Propulsion

Based on a review of pertinent atomic physics and electromagnetic theory, the particle and continuum representations of ionized gas dynamics are developed and applied to various electro-thermal, electrostatic, and electromagnetic acceleration mechanisms, each illustrated by various thruster designs, contemporary applications, and performances. (Offered in alternate years)

524 Plasma Engineering

The purpose of this course is to expose interested graduate and undergraduate students in engineering and the natural sciences to basic aspects of plasma physics and chemistry applicable to a variety of technologies, such as plasma propulsion, lasers, and materials processing. It involves extension of classical fluid mechanics, kinetic theory, statistical thermodynamics, and reaction engineering methods to relatively-low-temperature plasmas in electric and magnetic fields. (Offered in alternate years)

525/ AST 551 General Plasma Physics I

Characterization of the plasma state, Debye length, plasma and cyclotron frequencies, collision rates and mean free paths, atomic processes, adiabatic invariance, orbit theory, magnetic confinement of single charged particles, two-fluid description, magnetohydrodynamic waves and instabilities, heat flow, diffusion, finite-pressure effects, kinetic description, and Landau damping.

527 Physics of Gases

Physical and chemical topics of basic importance in modern fluid mechanics, plasma dynamics, and combustion science: statistical calculations of thermodynamic properties of gases; chemical and physical equilibria; adiabatic temperatures of complex reacting systems; quantum mechanical analysis of atomic and molecular structure and atomic-scale collision phenomena; transport properties; reaction kinetics, including chemical, vibrational, and ionization phenomena; and propagation, emission, and absorption of radiation.

529,530 Advanced Topics in Applied Physics I, II

Selected topics in applied physics, with an emphasis on advances relevant to research activities represented in the department. Possible topics include advanced plasma propulsion, linear and nonlinear wave phenomena, and x-ray lasers in biological investigations.

531 Combustion

Fundamentals of combustion: thermodynamics; chemical kinetics; explosive and general oxidative characteristics of fuels; premixed and diffusion flames; laminar and turbulent flame phenomena; ignition and flame stabilization; detonation, environmental combustion considerations; and coal combustion.

532 Combustion Theory

Theoretical aspects of combustion: the conservation equations of chemically-reacting flows; activation energy asymptotics; chemical and dynamic structures of laminar premixed and non-premixed flames; aerodynamics and stabilization of flames; pattern formation and geometry of flame surfaces; ignition, extinction, and flammability phenomena; turbulent combustion; boundary layer combustion; droplet, particle, and spray combustion; and detonation and flame stabilization in supersonic flows.

533 Rocket and Air-Breathing Propulsion Technology

Characteristics and fundamentals of aircraft and spacecraft chemical propulsion systems are studied. The characteristics explain their optimal operating ranges. The fundamentals elucidate their limitations and potentials. The organization and extent of the material are similar to those of standard textbooks. Important details are pursued with the help of specialized reference.

539, 540 Advanced Topics in Combustion I, II

Selected topics in theoretical and experimental combustion, with an emphasis on advances relevant to research activities represented in the department. Possible topics include turbulent combustion, theoretical calculations of rate constants, plasma fuels and natural resources, and nuclear propulsion power plants.

541/APC 571 Applied Dynamical Systems

Phase-plane methods and single-degree-of-freedom nonlinear oscillators; invariant manifolds, local and global analysis, structural stability and bifurcation, center manifolds, and normal forms; averaging and perturbation methods, forced oscillations, homoclinic orbits, and chaos; and Melnikov's method, the Smale horseshoe, symbolic dynamics, and strange attractors. (Offered in alternate years)

542 Advanced Dynamics

Principles and methods for formulating and analyzing mathematical models of physical systems; Newtonian, Lagrangian, and Hamiltonian formulations of particle and rigid and elastic body dynamics; canonical transformations, Hamilton-Jacob-Jacobi Theory; and integrable and non-integrable systems. Additional topics are explored at the discretion of the instructor.

543 Advanced Orbital Mechanisms

An advanced course in orbital motion of earth satellites, interplanetary probes, and celestial mechanics. Topics include orbit specification, orbit determination, Lambert's problem, Hill's equations, intercept and rendezvous, air-drag and radiation pressure, Lagrange points, numerical methods, general perturbations and variation of parameters, earth-shape effects on orbits, Hamiltonian treatment of orbits, Lagrange's planetary equations, orbit resonances, and higher-order perturbation effects. (Offered in alternate years)

544 Aircraft Dynamics

Linear and nonlinear models of aircraft dynamic characteristics; stability and control analysis, using state-space and classical formats; longitudinal and lateral-directional motion including aerodynamic and inertial coupling effects; handling qualities criteria; applications of catastrophic theory and bifurcation analysis in flight dynamics; and problems related to density gradient, aeroelasticity, wind shear, and turbulence. (Offered in alternate years)

545 Nonlinear Control

Nonlinear control of dynamical systems, with an emphasis on the geometric approach. The course gives an introduction to differential geometry, nonlinear controllability and constructive controllability, nonlinear observability, state-space transformations and stability, followed by study of a selection of nonlinear control design methods, including techniques motivated by geometric mechanics. (Offered in alternate years)

546 Optimal Control and Estimation

An introduction to stochastic optimal control theory and application. It reviews mathematical foundations and explores parametric optimization, conditions for optimality, constraints and singular control, numerical optimization, and neighboring-optimal solutions. Least-squares estimates, propagation of state estimates and uncertainty, and optimal filters and predictors; optimal control in the presence of uncertainty; certainty equivalence and the linear-quadratic-Gaussian regulator problem; frequency-domain solutions for linear multivariable systems and robustness of closed-loop control are all studied.

547 Linear System Theory

Advanced topics in linear system analysis. The course gives a review of linear vector spaces and differential equations. It covers characterization of continuous and discrete time linear systems, transfer functions and state-space representations, properties of transition matrices, observability and controllability, minimal realizations, stability, feedback, and pole assignment.

548/ ELE 523 Nonlinear System Theory

Mathematical techniques useful in the analysis and design of nonlinear systems. Topics include stability and qualitative behavior of differential equations, functional analysis and input/output behavior of systems, and "modern" nonlinear system theory, which uses both geometric and algebraic techniques. Prerequisite: 547.

549, 550 Advanced Topics in Dynamics and Control I, II

Selected topics in dynamics and control, with an emphasis on advances relevant to research activities represented in the department. Possible topics include bifurcation theory, nonlinear mechanics, system identification, intelligent control, learning control, and applied aerodynamics.

551 Fluid Mechanics

An introduction to fluid mechanics. The course explores the development of basic conservation laws in integral and differential forms: one-dimensional compressible flows, shocks and expansion waves; effects of energy addition and friction; unsteady and two-dimensional flows and method of characteristics. Reviews classical incompressible flow concepts, including vorticity, circulation, and potential flows. Introduces viscous and diffusive phenomena.

552 Viscous Flows and Boundary Layers

The mechanics of viscous flows. The course explores the kinematics and dynamics of viscous flows; solution of the Navier Stokes equations; the behavior of vorticity; the boundary layer approximation; laminar boundary layer with and without pressure gradient; separation; integral relations and approximate methods; compressible laminar boundary layers; instability and transition; and turbulent boundary layers and self-preserving turbulent shear flows.

553 Turbulent Flow

Physical and statistical descriptions of turbulence; and a critical review of phenomenological theories for turbulent flows. The course examines scales of motion; correlations and spectra; homogeneous turbulent flows; inhomogeneous shear flows; turbulent flows in pipes and channels; turbulent boundary layers; calculation methods for turbulent flows (Reynolds stress equations, LES, DNS); and current directions in turbulence research.

554 Stability and Turbulence

Hydrodynamic stability: inviscid theory; viscous theory; complex physics; and numerical analysis. The course examines nonlinear stability theory: nonlinear theory; secondary and elliptic instability; theories of transition; dynamics of defects; and numerical simulations. Introduction to the mathematical theory of chaos; turbulence: qualitative properties of turbulence; and introduction to turbulence transport modeling.

555 Non-Equilibrium Gasdynamics

Noncontinuum description of fluid flow and Liouville and Boltzmann equations. The course examines molecular collisions; detailed balancing; Chapman-Enskog expansion for near-equilibrium flows; transport phenomena; flows with translational, vibrational and chemical non-equilibrium; shock structure; and shear and mixing layers with chemical reactions.

557 Simulation and Modeling of Fluid Flows

Numerical methods are applied to solve the equations that govern fluid motion. Fluid flow problems involve convection, diffusion, and source terms. The governing equations are non-linear and coupled. Finite-difference and finite volume methods are considered, together with concepts of accuracy, consistency, stability, convergence, conservation, and shock capturing. A range of current methods is reviewed with emphasis on multidimensional steady and unsteady compressible flows. Homework topics include writing codes to solve the conservation equation for a scalar, boundary layer flow, shock tube flow, application to curvilinear coordinates.

558 Simulation and Modeling of Turbulent Fluid Flows

The foundation of CFD as applied to turbulent flows. Concepts of numerical accuracy and bandwidth are introduced. Aliasing and Nyquist criteria are discussed. Solutions in differential form and wave space are studied. The numerical representation of turbulent transport, production, and dissipation are discussed. Techniques for the simulation and modeling of turbulent flows are described, including direct numerical simulation (DNS), large-eddy simulation (LES), and Reynolds-averaged Navier-Stokes (RANS). Homework topics include writing codes to solve isotropic turbulence using DNS, LES, and RANS methodologies.

559, 560 Advanced Topics in Fluid Mechanics I, II

Selected topics in fluid mechanics, with an emphasis on advances relevant to research activities represented in the department. Possible topics include advanced computational fluid dynamics, turbulence in fluids and plasmas, hydrodynamic stability and turbulence.

561 (MSE 501) Introduction to Materials

Emphasizes the connection between microstructural features of materials (e.g., grain size, boundary regions between grains, defects) and their properties, and how processing conditions control structure. Topics include thermodynamics and phase equilibria, microstructure, diffusion, kinetics of phase transitions, nucleation and crystal growth, phase separation, spinodal decomposition, glass formation, and the glass transition.

562 (MSE 540) Fracture Mechanics

Fracture involves processes at multiple time and length scales. This course covers the basic topics, including energy balance, crack tip fields, toughness, dissipation processes, and subcritical cracking. Fracture processes are then examined as they occur in some modern technologies, such as advanced ceramics, coatings, composites, and integrated circuits. The course also explores fracture at high temperatures and crack nucleation processes. (Offered in alternate years)

563 (MSE 504) Modeling and Simulation in Materials Science

This course examines methods for simulating materials on the electronic, atomistic, microstructural, and continuum scales and approaches for connecting across length scales. The scientific underpinning of each is emphasized. Hands-on experience in writing and/or exercising simulation codes on all scales is provided.

564 (MSE 512) Structural Materials

Stress/strain behavior of materials; dislocation theory and strengthening mechanisms; yield strength; materials selection. Fundamentals of plasticity, Tresca and Von Mises yield criteria. Case study on forging: upper and lower bounds. Basic elements of fracture. Fracture mechanics. Mechanisms of fracture. The fracture toughness. Case studies and design. Fatigue mechanisms and life-prediction methodologies. (Offered in alternate years)

566 (MSE 502) Thermodynamics and Kinetics of Materials

Thermodynamics and kinetics applicable to phase changes and processing in broad range of materials (metals, oxides, polymers, colloids, gels, surfactants). Phase equilibrium (including effects of curvature), nucleation, crystallization, phase separation, diffusion in liquids and solids, colloidal stability, flocculation and gelation, glass transition.

569, 570 Advanced Topics in Materials and Mechanical Systems I, II

Selected topics in materials and mechanical systems, with an emphasis on advances relevant to research activities represented in the department. Possible topics include high temperature protective coatings, multifunctional materials, MEMS, advanced computational methods in materials engineering.

579, 580 Advanced Topics in Energy and Environment I, II

Selected topics in energy and the environment, with an emphasis on advances relevant to research activities represented in the department. Possible topics include combustion control and emissions, economic development and energy resources, and energy efficiency.

597, 598 Graduate Seminar in Mechanical and Aerospace Engineering

A seminar of graduate students and staff presenting the results of their research and recent advances in flights, space, and surface transportation; fluid mechanics; energy conversion; propulsion; combustion; environmental studies; applied physics; and materials sciences. There is one seminar per week and participation at presentations by distinguished outside speakers.

7. Typical Student Schedule

Semester 1	4 Courses- one math, 2 major, 1 minor
Semester 2	3 Courses- one math, 1 major, 1 minor/or extra
1st Summer	Research and Minor General Exam Preparation
Semester 3	1 Course, minor or extra; General Exam Interviews and Preparation; Subject General Examination
Semester 4	Possible AI, Research, Preparation for Research General Examination and Research General Exam
2nd Summer	Research
Subsequent Semesters	Complete 3 AI assignments, Research