PRINCETON UNIVERSITY
Department of Mechanical and Aerospace Engineering

INFORMATION FOR GUIDANCE OF GRADUATE STUDENTS

2015-2016 Edition

The information provided in this guide was developed with the assistance of the Graduate Student Committee and supersedes all prior documents. Its contents have been approved by the MAE Faculty and represent the Department's graduate education policy.

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1. Introduction

The Mechanical and Aerospace Engineering Department at Princeton performs cutting edge research in a multitude of engineering disciplines, incorporating graduate students into every aspect of its mission. It is the goal of the department to create a flexible, yet rigorous, educational environment where students can develop expertise in their discipline while developing an appreciation for the scope of opportunities and areas to which they can contribute. To this end we strive to:

-Educate students in the fundamentals of their discipline and the underlying mathematical foundation, pushing them to achieve mastery of a field.

-Stretch students into other areas, providing exposure to the scope of problems approachable by areas of MAE.

-Provide the confidence and skills to succeed in an increasingly interdisciplinary environment and the ability and independence to learn and work in new areas and applications.

-Teach the fundamental skills of independent research and provide the opportunity to investigate and solve an extended research problem in depth.

-Provide opportunities to teach and mentor undergraduates.

-Help students build an identity within the community, develop speaking and writing skills to excel, and provide them experiences to further their career.

-Provide an environment where students gain intellectual growth and experience by working closely with a research advisor and interacting regularly with department faculty.

To accomplish its educational mission, 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 part 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. Advising

2.1 Finding an Advisor

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

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 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. Students will also be given the option to take one or more research courses with faculty in an effort to assist in determining their Ph.D. advisor. Students will be given an Advisor Selection form in the fall of their first year and will identify their thesis advisor by the end of the Student Reenrollment period in March.

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 availability. 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.

2.1.1. 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 situation, 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. The 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 and new advisor must sign a Change of Advisor Form and submit it to the Director of Graduate Studies indicating agreement with the decision to change advisors.

2.2 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 and Ph.D. committee. The Departmental Faculty Graduate Committee considers all reenrollment applications for the following academic year in the spring term.

In order to be reenrolled into 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 (3.0) or better, with only one "C", and ii) completion of the University English language requirement necessary for appointment as an Assistant-in-Instruction (see Section 2.3).

A MSE student must maintain a course performance with an average of B (3.0) or better with only one "C", 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.

2.2.1 Ph.D. Committee

Prior to reenrollment, PhD students who have passed the general exam, will be required to meet with their Ph.D. committee annually to give a short presentation of their research and get feedback on direction. Students entering their 5th year must present a plan describing what they will do to finish their dissertation work. This will require that they meet with their advisor before the Ph.D. committee meeting to discuss what will be required.

A Ph.D. Committee Meeting form must be completed and uploaded by the student into their reenrollment comments in TigerHub by the end of the reenrollment period.

2.3 English Language Proficiency

Graduate students must demonstrate a level of oral proficiency in the English language sufficient to participate successfully in all the various activities that comprise a graduate education, including classwork, research, research presentations, group meetings, project teamwork, and the teaching of undergraduates. Graduate students must comply with the English Language Proficiency policy mandated by the Graduate School:

http://gradschool.princeton.edu/policies/english-language-proficiency

The Graduate School requires that all non-native speakers of English who have not earned their undergraduate degree in a U.S. college or university and who scored below a 28 on the Speaking sub-section of the TOEFL iBT or below an 8.0 on the Speaking sub-section of the IELTS have their oral English proficiency evaluated by the ELP staff. At the start of the fall term, such students will be given placement tests to evaluate their oral English proficiency by the ELP staff. The Graduate School has established that passing either the placement test or the Princeton Oral Proficiency Test (POPT) qualifies a graduate student to be appointed as an assistant in instruction (AI) and attests to the student's basic proficiency in spoken English. The department requires that a student who does not pass the 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.

2.4 Registration

All students are required to register in September on the date specified by the Graduate School. Also at that time, students must register through TigerHub for courses. Registration for the spring term is accomplished by completing course registration through TigerHub.

2.4.1. 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. With the permission of the Departmental Graduate Committee and the Graduate School, students in good standing in the Ph.D. program may transfer from the Ph.D program to the M.S.E. program to satisfy newly realized goals. It is not possible, however, to transfer into the Ph.D. program from one of the master's tracks or into the M.Eng. program from either the M.S.E. or Ph.D. track.

3. 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" (3.0) average in their courses with only one "C". The degree requirements comply with the regulations of the Graduate School concerning admissions, residence, program structure, and time to completion of the degree.

3.1 The Ph.D. Program

The Ph.D. program is typically five 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. 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 one pre-Generals interview, 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 a minimum of three semester courses (See Section 3.1.8). 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.

3.1.1 Requirements for the Ph.D. Degree

While the department encourages interdisciplinary research and education, it also recognizes the value of developing competency in a core disciplinary area. The Ph.D. requirements are thus designed to provide students a deep education in a disciplinary area of the department while also requiring an area of breadth consistent with the student's research interests and program of study. Entering students are thus expected to select one of the six departmental disciplines as their major area of study: Applied Physics, Combustion/Thermal Science, Control and Dynamical Systems, Fluid Mechanics, Mechanics and Materials, or Applied Math and Computation.

They must then meet the following requirements to receive the Ph.D. degree:

Take at least 8 courses for credit (or 7 courses plus a research experience) prior to standing for the General Examination.

Take at least 4 courses from their declared major disciplinary area, not including a research experience. Section 5 provides departmental graduate course descriptions and lists the core courses in the six departmental areas of concentration.

Take at least two breadth courses, selected in consultation with the advisor and the Ph.D. committee, from outside the student's major area and consistent with the student's program of study, prior to completing the degree program.

Take at least 2 courses in mathematics (from the approved list in Section 5) prior to standing for the General Examination.

Take at least 10 courses (or 9 courses plus a research experience) before standing for the FPO.

Complete a half-semester course on the Responsible Conduct of Research.

Maintain a 3.0 average or better in all course work, with only one "C".

Complete a pre-general interview in the major area of study with a faculty member associated with the area.

Pass both the subject and research components of the General Examination.

Complete a minimum of 3 semesters as an Assistant-In-Instruction (AI) after passing the General Examination.

Complete a written thesis and pass a Final Public Oral (FPO) presentation of their research.

Students normally take seven approved courses for credit during their first year. Taking at least seven courses in the first year permits a student to concentrate on the pre-general interview and research in the Fall term of the second year. Courses taken prior to arriving at Princeton can be substituted with permission of the Graduate Committee. The course of study and research should be selected so that the Ph.D. program can be completed in no more than five years.

In addition to the eight course requirement all Ph.D. and MSE candidates are required to take EGR501 in the fall term of their second year. This course educates the graduate student of engineering in the responsible conduct of research. The lectures provide theoretical background information as well as case studies about ethics in day-to-day research situations, in publishing and peer-review, in student-advisor relationships, in collaborative research, as well as in the big picture and considerations of long-term impact. The students are provided resources to consult when faced with ethical questions. The theoretical concepts are made relevant to the individual students situations via small-group discussions in departmental and research field-specific precepts.

3.1.2 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 indicated their desire to stand for the General Exam.

3.1.3 Advisory Committee for Ph.D. Candidates

Prior to the beginning of the first 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. Students will meet with their advisory committee annually to give short presentations on their research and to get feedback on direction. 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.

3.1.4 The Intramural Research Experience

The department recognizes that some students arrive at Princeton uncertain of their desired research direction or without a firm interest or commitment to work with a specific faculty member. The intramural research experience allows students to begin research in their first year and explore the research possibilities offered by the department. This is a one-semester independent study with a faculty member on a small research project chosen jointly by the student and faculty member. The project culminates in a written paper, in the style of a journal article, and a 15-20 minute presentation to at least one faculty member from the department who was involved in the research project. The student will receive a letter grade for the project.

Pre-generals students may elect to use the research experience as a substitute for one of the required 8 courses prior to the general exam. Note that it is not a substitute for one of the 4 courses from the declared major disciplinary area. Post-generals students who have not already substituted a research experience may elect to use a research experience as a substitute for one of the required 10 courses provided it is with a faculty member different from the student's Ph.D. advisor. Note that students may elect to participate in

more than one research experience (for instance, in both the first and second semester of the first-year to explore different faculty research instances) but only one may be used as a substitute for the course requirements.

Students interested in participating in a research experience must notify the graduate program administrator at the start of the term via email with the name of the faculty that they are working with and the topic of the project. The student must have the faculty mentor certify successful completion at the end of the term.

3.1.5 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 measure the student's knowledge of fundamentals and the ability to integrate material across courses in a major area of depth.

2. To determine the creative potential of the student to conduct Ph.D. level research.

3. To motivate the student to review and synthesize course work and research material.

4. To develop and test the student's ability to communicate material orally and respond to questions and comments.

The general examination process consists of three components: i) one pre-general interview completed during the fall of second year, ii) an oral examination taken in January of the second year (the "subject component") in the student's major disciplinary area of study 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 with only one "C".

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.
See Sec. 2.3.

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. The expectation is that the student will successfully complete both of these components by May of the second year. The various failure scenarios are described in Section 3.1.5f. The following is a typical general exam schedule; exceptions to this schedule are made only by petition and approval of the graduate committee.

3.1.5a General Examination Schedule

July and August – Concentration on research and studying for the subject component and interview

September – Complete any needed courses; prepare for exam

October – Submit Examiner Request form

November– Complete interview and submit Pre-General Interview form

January – Subject component of general exam

May – Research component of general exam

3.1.5b Pre-Generals Coursework

Students are expected to take eight courses for a letter 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, MAE 501 and MAE 502, and four must be in the primary area of research. The remainders are expected to be relevant technical courses. For students initially unsure of their research direction, a single one-semester research experience (see Section 3.1.4) may be substituted for one of the eight courses. A research experience is not a substitute for one of the required four courses from the major area. All students are expected to take four courses in their first semester or three courses plus a research experience. Students must achieve an average grade of 3.0 or higher in these courses to stand for the general exam. If a student does not receive a B or better in both of their required math courses, they will be required to take a 30 min oral math exam prior to or during the subject component exam. Qualification for taking the general exam is made by the graduate committee based upon information supplied on the Examiner Request form.

Please note that some courses are offered Pass/Fail only. All eight pre-generals courses must be taken for a letter grade. If the course is offered Pass/Fail, the student must make arrangements with the faculty in advance to receive a letter grade. If these arrangements cannot be made, then the course cannot count as a pre-generals course,

3.1.5c The Pre-General Interview

Students will be given a single oral interview in the fall of their second year by a faculty member chosen by the major group. In case of an interdisciplinary program of study spanning two major areas, separate interviews in both areas are required. A student who is taking the math exam must also have a separate math interview. A list of available interviewers and their subjects is available online and in the graduate office. 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 and to inform the graduate committee of the student’s readiness for 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.

The MAE Graduate Office maintains a list of faculty who are available to give interviews in the various subject areas. 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 are not available, it is preferred to use a course instructor, rather than the interviewer or advisor, as an examiner. Students are 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 the interview, the interviewer submits a signed Pre-General Interview 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.

3.1.5d 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 student's undergraduate and graduate course work. 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 adequate preparation to succeed in the subject component of the general exam.

The Subject Component is a 90 minute oral examination given by two faculty members and chaired by a member of the faculty 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, however, at least one examiner must be from the major area of study and a member of the MAE Department.

The student is expected to be conversant in the following applied math topics, all covered in MAE 501, 502. (If a B or better is not achieved in one or both courses the student will be required to stand for a math component during the subject exam).

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

The student, together with the advisor, selects 4 examiners for the major on the Examiner Request Form. The Graduate Office will assign 2 examiners from this list. If the student is required to take the Math Subject Component they will need to list 3 possible math examiners. 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. In case of program of study spanning two major areas, 1 examiner from each area will be chosen.

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

3.1.5e 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 faculty as chair. 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.

3.1.5f 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:

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. If the student was required to take both a Math and Major Area exam, and only fails one component, they will only be required to retake that component.

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.

Pass Subject Component but Perform Poorly on First Try at Research Component – There are three possibilities for a student who passes the subject component the first time but performs poorly on the first try at the research component. 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 the next exam period. 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.

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.

Fail Subject Component in January, Pass in May, Fail Research Component: – There are two possibilities for a student who passes the subject component in May after failing in January, but performs poorly on the first try at the research component in May or 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 committee gives the student a “Fail” on the research component and recommends that the student complete an MSE thesis and degree. The second possibility is that the committee can give the student a “Terminal Pass” which means the student leaves with an M.A. degree.

3.1.6 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 Advanced Degree Application Form online via TigerHub. Application for this degree can be made any time after the student passes the General Examination.

3.1.7 Post-Generals Courses

Post-generals students will be required to take a minimum of two additional graduate level courses, at their leisure, so that the total number of courses taken is at least ten. Further, these two courses can be taken for a grade or as P/F. This is independent of the three-course (minimum) 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. With the advisor’s consent, a beginning language course may be selected, but it must be taken for a full year.

3.1.8 Assistant-In-Instruction

It is a requirement for students to complete a minimum of 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. Requests for particular assignments will be accommodated 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 10-12 hours of work for the AI assignment per week. This will allow you to maintain some research projects during the semester. First time AIs will be required to attend the Mandatory AI training in September or February, prior to their AI assignment.

3.1.8a 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 for assisting the students to grasp/master the concepts discussed in the course. The precepts are typically structured to clarify lectures, review problem sets and prepare for examinations, etc. This aspect of the AI assignment 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.

3.1.8b 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. This is a guideline, it is not a rule and 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 are required to be available for students and faculty during those times.

The McGraw Center for Teaching and Learning holds a Teaching & Orientation Conference in the fall and spring for all new and experienced AIs. It is typically a two day conference in early September and February which all new AIs will be required to attend.

3.1.9 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 Faculty 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. The student and advisor should petition the MAE Faculty Graduate Committee. The Faculty Committee is permitted to vote to receive a dissertation that is submitted later than the five-year limit. Students anticipating a delay in presenting the final dissertation should keep the Department informed, so that their progress can be appropriately monitored.

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 must be approved by the Graduate School by submitting a curriculum vitae for the outside reader.

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://rbsc.princeton.edu/services/theses-dissertations

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."

One copy of the final dissertation shall be submitted to the MAE Graduate Office for reading by the faculty. This copy will be kept for two weeks in the MAE Graduate Office. One bound copy will go to Mudd Library upon successful completion of the Final Public Oral. At the same time, copies of the dissertation shall also be given to the two designated examiners for the Final Public Oral Examination. A memorandum announcing that the student's dissertation is available for reading along with the Reader's Reports will be submitted to the Department faculty. At least two weeks must elapse between the submission of the final copy 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 copy of the dissertation is submitted to the MAE Graduate Office, the candidate must complete the online Advanced Degree Application Form via TigerHub. The student should review the Ph.D. Checklist to see all that is required and when it should be submitted.

http://gradschool.princeton.edu/sites/gradschool/files/checklist_phd_defense_0.pdf

The student should complete the Checkout for Students Departing the University form.

http://gradschool.princeton.edu/sites/gradschool/files/Student%20Checkout.pdf

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.

3.1.10 The Final Public Oral Examination

Permission to hold the Final Public Oral Examination will be given only after all required forms have been submitted through TigerHub and the final copy of the dissertation has been submitted to the Graduate Office. After permission to hold the Final Public Oral Examination is granted by the Graduate School, the graduate office will distribute to the faculty the memo and announcement of the Examination.

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 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.

See:

http://gradschool.princeton.edu/academics/degree-requirements/phd-requirements/dissertation-and-fpo

http://gradschool.princeton.edu/academics/degree-requirements/phd-requirements/dissertation-and-fpo/advanced-degree-application

3.2 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.

3.2.1 Requirements for the MSE Degree

To qualify for the MSE 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.

See: http://gradschool.princeton.edu/academics/degree-requirements

3.2.2 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. The suitability of a reader from industry, government, or another university must be approved by the Graduate School by submitting a curriculum vitae for the outside reader. The suggestions of both the advisor and the reader shall be considered, and their approval secured, before submission of the final copy 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.

One final copy 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://rbsc.princeton.edu/services/theses-dissertations

The online Advanced Degree Application form must be submitted before the student is recommended for the MSE degree. This must be filled out electronically via TigerHub.
Master's degrees are awarded five times during the academic year. These times correspond to the September, November, January, April and June meetings of the Board of Trustees, and are listed on the Degree Application form. Two bound copies of the thesis must then be taken to Mudd Library.

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.

3.3 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.

3.3.1 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.

3.3.2 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 a 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.

4. Miscellaneous

4.1 Graduate Student Committee

The Graduate Student Committee is organized in accordance with the University's "Rights, Rules, and Responsibilities." This Committee represents the interests of the graduate student body of the Department. A representative from each year is elected as 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.

4.2 MAE Graduate Student Vacation Policy

Departmental vacation policy is consistent with the Graduate School guidelines, which state:

Graduate study is understood to be a full-time commitment on the part of students. During an academic year, which includes the summer, graduate student degree candidates may take up to (but no more than) four weeks of vacation, including any days taken during regular University holidays and scheduled recesses (e.g., the fall- and spring- term breaks and inter-term break). The specific periods taken as vacation must not conflict with the student's academic responsibilities, coursework, research, or teaching, and should be discussed in advance with one's director of graduate studies, adviser, or dissertation committee. If a student receives financial support for graduate study for only part of the year (e.g., regular term time, September 1 to June 30), then the amount of vacation should be prorated accordingly. If a student receives summer support and has taken the allowed vacation during regular term time, September 1 to June 30, then he or she should not take additional vacation time during the summer months of July and August. If a student holds an external fellowship whose terms may conflict with this guideline, the student should consult first with the director of graduate studies or adviser. http://gradschool.princeton.edu/policies/student-vacation-time

4.3 Office Space, Keys to Laboratories, Mailbox

Students will be assigned office desk space. Any questions should be directed to the MAE Graduate Office assistant 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 (D209).

4.4 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. The department offers the Daniel and Florence Guggenheim Foundation Fellowship, the Howard Crathorne Phillips Graduate Fellowship, the Martin Summerfield Graduate Fellowship to second year students who have been chosen as showing exemplary work in both studies and research in their first year. The Brit and Eli Harari Post Generals Fellowship is awarded to a post generals international student who has demonstrated excellence in both academics and research. These fellowships cover all or part of the student's tuition and stipend. The department also offers the following cash prizes to selected students: the Luigi Crocco Prize is awarded to an outstanding Assistant-in-Instruction from the prior year; the Larisse Rosentweig Klein Prize recognizes a woman student in the

third year, or beyond who has shown exemplary research capability; the Athena-Feron Prize is awarded to an upcoming second or third year student who has objectively embraced, completed and excelled in substantially more mathematical courses than the strict required MAE501/502 sequence.

The Graduate School offers Honorific Fellowships, and the department nominates two top students entering their final dissertation year for this award.

4.5 Outside Fellowships

MAE encourages students to apply for outside fellowships. 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.

5. Departmental Graduate Courses

501/APC 501 Mathematical Methods of Engineering Analysis I
A complementary presentation of theory, analytical methods, and numerical methods for the solution of problems in physics and engineering. Topics include an introduction to functional analysis, linear spaces and linear operators, including matrices, eigenproblems and Sturm-Liouville theory; basic ordinary differential equation (ODE) theory, Green's functions for the solution of linear ODEs and Poisson's equation, and the calculus of variations.

502 Mathematical Methods of Engineering Analysis II
A continuation of MAE 501. Complex variables, including contour integration using residues and conformal mapping; Fourier and Laplace transforms; linear partial differential equations (hyperbolic, parabolic and elliptic PDEs) and solution methods; traveling waves for nonlinear PDE; an introduction to numerical methods for ODEs and PDEs, and regular perturbation methods.

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 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.

528/AST 566 Physics of Plasma Propulsion
Focus of this course is on fundamental processes in plasma thrusters for spacecraft propulsion with emphasis on recent research findings. Start with a review of the fundamentals of mass, momentum & energy transport in collisional plasmas, wall effects, & collective (wave) effects, & derive a generalized Ohm's law useful for discussing various plasma thruster concepts. Move to detailed discussions of the acceleration & dissipation mechanisms in Hall thrusters, mangetoplasmadynamic thrusters, pulsed plasma thrusters, & inductive plasma thrusters, & derive expressions for the propulsive efficiencies of each of these concepts.

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.

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)

545 Special Topics in Mechanical & Aerospace Engineering
Topics vary.

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/ELE521 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. This course covers topics in nonlinear dynamical systems including qualitative behavior, Lyapunov stability, input-output stability, passivity, averaging and singular perturbations. (offered in alternate years)

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.

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.

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, low Reynolds number hydrodynamics, and capillary phenomena.

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)

MSE 452 Phase Transformations and Evolving Microstructures in Hard and Soft Matter Systems
This course covers the fundamental principles of thermodynamics and phase transformation kinetics in hard and soft matter systems, such as metals and alloys, semiconductors, polymers, and lipid bilayer membranes. The course synthesizes descriptive observations, principles of statistical thermodynamics, and mathematical theories to address emergent physical, chemical, mechanical, and biological properties of multi-component, multiphase materials systems.

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.

5.1 Courses Offered That Will Fulfill Each Disciplines Four Course Requirement

** Indicates Core Courses required by discipline

5.1.1 Dynamics and Controls

433 Automatic Control Systems **
434 Modern Control **
541/APC 571 Applied Dynamical Systems
542 Advanced Dynamics **
543 Advanced Orbital Mechanics
544 Aircraft Dynamics
546 Optimal Control and Estimation **
547/ELE521 Linear System Theory
548/ELE523 Nonlinear System Theory
549, 550 Advanced Topics in Dynamics and Control I, II

5.1.2 Fluid Mechanics

527 Physics of Gases
539 Topics in Combustion I: Turbulent Combustion
551 Fluid Mechanics **
552 Viscous Flows and Boundary Layers **
553 Turbulent Flow
555 Non-Equilibrium Gasdynamics
557 Simulation and Modeling of Fluid Flows
559, 560 Advanced Topics in Fluid Mechanics I, II
AOS571 Introduction to Geophysical Fluid Dynamics
AOS573 Physical Oceanography
AST523/APC523 Scientific Computation in Astrophysics
CBE533/MSE523 Introduction to the Mechanics and Dynamics of Soft Living Matter

5.1.3 Combustion and Thermal Science

426 Rocket and Air Breathing Propulsion
427 Fossil Fuel Energy Conversion: Mobile Power Plants
527 Physics of Gases
531 Combustion **
532 Combustion Theory
539, 540 Advanced Topics in Combustion I, II
551 Fluid Mechanics **
552 Viscous Flows & Boundary Layers
553 Turbulent Flows
555 Non-Equilibrium Gas Dynamics **
579, 580 Advanced Topics in Energy and Environment I, II
WWS585b/MAE580 Living in a Greenhouse: Technology and Policy

5.1.4 Mechanics and Materials

MSE 452 Phase Transformations and Evolving Microstructures **
534 Energy Storage Systems
561/MSE 501 Introduction to Materials **
562/MSE 540 Fracture Mechanics
563/MSE 504 Modeling and Simulation in Materials Science
564/MSE 512 Structural Materials
569, 570 Advanced Topics in Materials and Mechanical Systems I, II
MSE505 Characterization of Materials **
MSE513/CHM511/MAE516 Introduction to Nanotechnology
ELE553/MSE553 Nonlinear Optics
ELE441 Solid State Physics I
ELE442 Solid State Physics II
ELE449 Materials and Solid-State Device Laboratory
ELE453 Optical Electronics
CBE526/CHM527/MSE526 Surface Science: Processes and Probes
CEE513 Introduction to Finite Element Methods
CEE521 Continuum Mechanics
CHM501 Introduction to Quantum Chemistry
CHM503 Introduction to Statistical Mechanics

5.1.5 Applied Physics

436 Special Topics – Direct Energy Conversion
511 Experimental Methods: Introduction to Electronics for Engineering and Science
512 Experimental Methods II
521 Optics and Lasers **
522/AST564 Applications of Quantum Mechanics to Spectroscopy and Lasers
524 Plasma Engineering
525/ AST 551 General Plasma Physics I
527 Physics of Gases **
528 Physics of Plasma Propulsion
529,530 Advanced Topics in Applied Physics I, II
AST552-General Plasma Physics II
AST553-Plasma Waves and Instabilities
AST554-Irreversible Processes in Plasmas
AST559-Turbulence in Plasma
AST560-Computational Methods in Plasma Physics
AST562-Laboratory in Plasma Physics
PHY501-Electricity and Magnetism
PHY505-Quantum Mechanics I
PHY511-Thermodynamic, Kinetic Theory & Stat Mech
CHM501-Introduction to Quantum Chemistry
CHM502-Advanced Quantum Chemistry
CHM503-Introduction to Statistical Mechanics
CHM504-Molecular Spectroscopy
CHM509, 510-Topics in Physical Chemistry
CHM512-Chemical Kinetics

5.1.6 Applied Math and Computation

501/APC 501 Mathematical Methods of Engineering Analysis I **
502 Mathematical Methods of Engineering Analysis II **
503/APC 504 Basic Numerical Methods for Ordinary and Partial Differential Equations
509, 510 Advanced Topics in Engineering Mathematics I, II
APC503/AST557 Analytical Techniques in Differential Equations I
APC509 Methods and Concepts in Electronic Structure Theory
AOS523/APC523 Scientific Computation in Astrophysics
AST560 Computational Methods in Astrophysics
MAT342 Numerical Methods

6. Travel and Reimbursement

All University-sponsored graduate student international travel must be registered in the travel registration system Concur. http://travel.princeton.edu/

Please note that a trip is considered sponsored by the University if:

-A University account contributes funds or money is held and disbursed through a University account (this includes your Graduate School stipend and funds supporting travel to international conferences, courses, or meetings).
-The trip is organized on behalf of a registered University organization, including but not limited to: student organizations, religious groups, sport clubs, varsity athletic teams, civic engagement organizations, residential colleges, academic or administrative departments.
-The trip is organized by a University faculty or staff member.
-The work will be considered for academic credit or is otherwise related to the student's program of study.

For information on this system and the process of registering travel, please review the following:

- https://travel.princeton.edu/graduate-students/graduate-travel-policies
- https://travel.princeton.edu/graduate-students/checklist
- http://gradschool.princeton.edu/academics/enrollment-statuses/degree-seeking-statuses/absentia/international-travel-advice

The registration process for international travel is considered to be part of the responsibilities that come along with being a Princeton graduate student, so please take the time to review these websites.

Travel Booking and Reimbursements

All travel booking and expense reimbursements will be done in the online system, Concur. Carlson Wagonlit Travel (CWT) is the University's travel management company working with Concur. When booking travel, Concur and/or CWT will be your primary source for creating business itineraries. Concur has capabilities similar to online travel websites such as Expedia which enable you to book your flight, train, hotel or rental car all in one location. CWT is a 24 hour multi-language travel agency.

In addition to travel booking, Concur will be the system that you use to request reimbursement of out-of-pocket travel and business expenses. With Concur you can take a picture of the receipt, scan or email it to concur@princeton.edu and easily create an expense report to route for approval and reimbursement. You will be automatically granted access to the Concur system as a graduate student. You will need to perform the one-time setup needed to create your profile to include personal information such as frequent flier numbers, seating preferences, passport information, etc. The Getting Started link on the Travel & Expense website will guide you through this process. Some basic information that you will need to setup your profile is listed below.

From the Profile tab, click Expense Approvers and type Theresa Russo's name in the field and select from the dropdown list. Click Save.

From the Profile tab, click Expense Information and enter the following information in the Department field: 25100

A few highlights about this travel and expense processes:

Paper receipts are no longer required. Pictures and scans of receipts must be legible.

Per diem will no longer be accepted. You must provide actual detailed receipts for meals and incidentals. Credit card receipts are not a sufficient substitute for the detailed receipt.

Reimbursement time is expected to be faster; approximately 48 hours after the expense report is approved.

Concur has built in policy features for items such as Fly America Act compliance and lowest logical airfare recommendations.

For more information please visit the PRIME portal: http://prime.princeton.edu/.

Important Campus Contacts

Please see information on the Graduate School website http://gradschool.princeton.edu/

Office of Public Safety Emergency (609) 258-3333 or 911

Public Safety General Information (609) 258-1000

University Health Services (609) 258-3141

Counseling and Psychological Services (CPS) (609) 258-3285

Counseling and Psychological Services Emergency (609) 258-3139

SHARE counselors (sexual harassment and assault support) (609)258-3310

Ombud's Office (609) 258-1775

Graduate Housing Office (609) 258-3460

Office of Disability Services (609) 258-8840

Davis International Center (609) 258-5006

Women's Center (609) 258-5565

LGBT Center (609) 258-1353