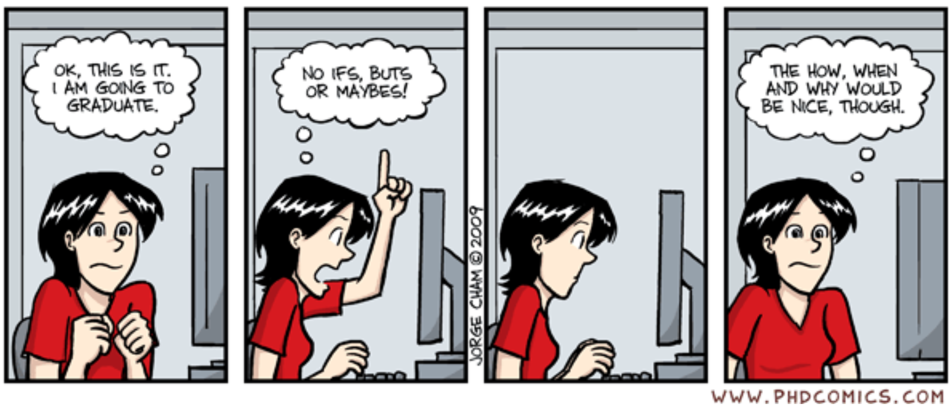
PRINCETON UNIVERSITY
Department of Mechanical and Aerospace Engineering

HANDBOOK FOR MAE GRADUATE STUDENTS



2023-2024 Edition

(August 16, 2023)

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.

1 Introduction **4**
2 Equity and Inclusion **5**
3 Advising **6**
3.1 Finding an Advisor 6
3.1.1 Change of (Co-)Advisors 6
3.2 Reenrollment 6
3.2.1 PhD Committee 7
3.3 English Language Proficiency 7
3.4 Registration 7
3.4.1 Changing Degree Programs 7
4 The PhD, MSE, and MEng Programs **9**
4.1 The PhD Program 9
4.1.1 Requirements for the PhD Degree 9
4.1.2 Advisory Committee for PhD Candidates 10
4.1.3 Pre-Generals Coursework 11
4.1.4 Seminar (MAE 597 and MAE 598) 11
4.1.5 Directed Research (MAE 503) 11
4.1.6 The General Examination 11
4.1.7 The Master of Arts Degree 14
4.1.8 Post-Generals Courses 14
4.1.9 Assistant in Instruction (AI) 14
4.1.10 The PhD Dissertation 16
4.1.10.A The Final Public Oral Examination 17
4.1.11 Internships (MAE 515 and MAE 595) 18
4.2 Master of Science in Engineering (MSE) Program 18
4.2.1 Requirements for the MSE Degree 19
4.2.2 The Master's Thesis 19
4.3 Master of Engineering (MEng) Program 20
5 Miscellaneous **21**
5.1 Graduate Student Committee 21
5.2 MAE Graduate Student Vacation Policy 21
5.3 Office Space, Keys to Laboratories, Mailbox 21
5.4 Department Prizes and Fellowships 21
5.5 Outside Fellowships 22
6 Departmental Graduate Courses **23**
6.1 Courses Offered in Each Departmental Discipline 31
6.1.1 Applied Physics 31
6.1.2 Biomechanics and Biomaterials 31
6.1.3 Dynamics and Controls 32
6.1.4 Fluid Mechanics 32
6.1.5 Materials Sciences 32
6.1.6 Propulsion and Energy Sciences 33
6.2 Pre-approved Math Courses 34
7 Travel Policy, Booking, and Reimbursement **35**
8 Important Campus Contacts **36**

MAE Directory

Chair: Naomi E. Leonard
Associate Chair: Michael E. Mueller
Director of Graduate Studies: Andrej Košmrlj (andrej@princeton.edu)

Professors
Craig B. Arnold
Emily A. Carter
Edgar Choueiri
Mikko Haataja
Marcus Hultmark
Yiguang Ju
Chung K. Law
Naomi E. Leonard
Michael G. Littman
Luigi Martinelli
Michael E. Mueller
Radhika Nagpal
Clarence W. Rowley III
Howard A. Stone

Associate Professors
Luc Deike
Alexander Glaser
Egemen Kolemen
Andrej Košmrlj
Julia Mikhailova
Daniel Nosenchuck

Assistant Professors
Christine Allen-Blanchette
Ryne Beeson
Daniel Cohen
Kelsey Hatzell
Jesse Jenkins
Anirudha Majumdar
Aditya Sood
Aimy Wissa

Emeritus Faculty in Residence
Philip J. Holmes
Alexander Smits
Robert Socolow
Szymon Suckewer

Visiting Faculty
Francesco Grasso

Graduate Program Administrator
Katerina Zara
D228 EQuad
Phone (609) 258-4683

Associated Faculty
Amir Ali Ahmadi (ORFE)
Elie Bou-Zeid (CEE)
Pierre-Thomas Brun (CBE)
Nathanial J. Fisch (AST)
Robert J. Goldston (AST)
Bruce E. Koel (CBE)
David J. McComas (AST)
Glaucio H. Paulino (CEE)
Salvatore Torquato (CHEM)
Robert J. Vanderbei (ORFE)
Claire White (CEE)

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 gaining an appreciation for the scope of opportunities and areas to which they can contribute. To this end, we strive to achieve the following goals:

- 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; and
- 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 (PhD), Master of Science in Engineering (MSE), and Master of Engineering (MEng). The PhD is a five- year program designed for a career in independent research and culminates in a doctoral dissertation. The MSE is a two-year program and requires an original thesis. The MEng is a one-year program with only coursework requirements.

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 found online at gradschool.princeton.edu. Additional useful information on rights, rules, and responsibilities can be found at rrr.princeton.edu.

2 Equity and Inclusion

The Department of Mechanical and Aerospace Engineering is committed to providing an open and supportive learning and professional environment for all students, faculty, and staff. As a community, we respect the dignity, individuality, and freedom of each member. At the same time, we strive to be a place where individuals and groups learn with and from each other. We aim to foster a sense of shared experience and common purpose, along with a collective responsibility for each other's well-being and for the well-being of the Department as a whole.

The Department is also committed to providing an environment that is free from all forms of discrimination, harassment, exploitation, or intimidation. Academic rigor and intellectual exchange of scientific ideas are integral parts of development as an independent engineer or scientist. All exchanges amongst members of the department must be done in a respectful manner and with understanding of the diversity of backgrounds within the community.

The Department aims to extend to each member of the community the resources necessary to achieve the highest levels of distinction in their work and research. These goals and values echo statements from campus-wide efforts.

On the following webpages you will find information and resources that support these efforts:

- Many Voices, One Future: Overview of the University's commitment and programs working toward diversity and inclusion.
- Student Resources: Information from the Graduate School on the available resources for current students that foster inclusion, intellectual growth, and quality of life.
- Sexual Misconduct and Title IX: Overview of the University's comprehensive program designed to protect members of the University community from sexual misconduct, including sexual harassment and sexual assault, stalking, and dating violence.
- Rules, Rights, and Responsibilities: Concise reference and guide for all members of the Princeton University community. Included here are brief statements of University policies most likely to be applicable to and of interest to all University constituencies.

MAE also has a Climate & Inclusion Committee, which seeks to enhance climate and ensure inclusion of all community members by facilitating communication amongst the Department community and between the community and the Department leadership. Graduate students are encouraged to discuss any matters of climate and inclusion, both specific and general, with the faculty co-chairs or the graduate representatives on the Committee.

3 Advising

3.1 Finding an Advisor

It is common for a particular professor or group of professors to indicate interest in working with a student at the time an admission offer is made. Nevertheless, to facilitate first-term advising, the department will appoint one or two faculty members to assist incoming graduate students with course selection in their first year.

For MSE/PhD students, the selection of a thesis/dissertation 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 holds a Research Day and Faculty Research Lunch Seminars early in the fall semester during which students and faculty members present brief talks about their research. It is hoped that this exposure will help entering students select a faculty thesis/dissertation advisor and permit them to become involved with a research program in the first or second semester. PhD students will also be given the option to take directed research courses with faculty in an effort to assist in determining their PhD advisor. MSE and PhD students will be given an Advisor Selection form and need to identify a thesis/dissertation advisor by the end of the reenrollment period in March/April.

Each faculty member can advise only 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.

3.1.1 Change of (Co-)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. The change must be discussed with the faculty member with whom the student wishes to become associated. That faculty member must be willing to accept the student and, unless the student has 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. Similarly, if a co-advisor is added after submission of the Advisor Selection form, then the advisor and new co-advisor must sign a Change of Advisor Form and submit it to the Director of Graduate Studies agree to addition.

3.2 Reenrollment

All PhD and MSE graduate students must apply formally for annual reenrollment. Reenrollment for MSE and PhD 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 into the second year of study with continuing PhD candidacy, a student must satisfy the following departmental requirements: first, a course performance with an average of B (3.0) or better; and, second, completion of the University English language requirement necessary for appointment as an Assistant-in-Instruction (see Section 3.3).

In order to be enrolled into the second year of study, a MSE student must maintain a course performance with an average of C (2.0) 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.

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.

3.2.1 PhD Committee

Prior to reenrollment, PhD students who have passed the general exam will be required to meet with their PhD Committee annually to give a short presentation of their research and get feedback on direction (see Section 4.1.2 for a description of the PhD Committee). 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 PhD committee meeting to discuss what will be required.

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

3.3 English Language Proficiency

Graduate students must demonstrate a level of oral proficiency in the English language sufficient to participate successfully in all the 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 (ELP) policy mandated by the Graduate School: gradschool.princeton.edu/policies/english-language-proficiency.

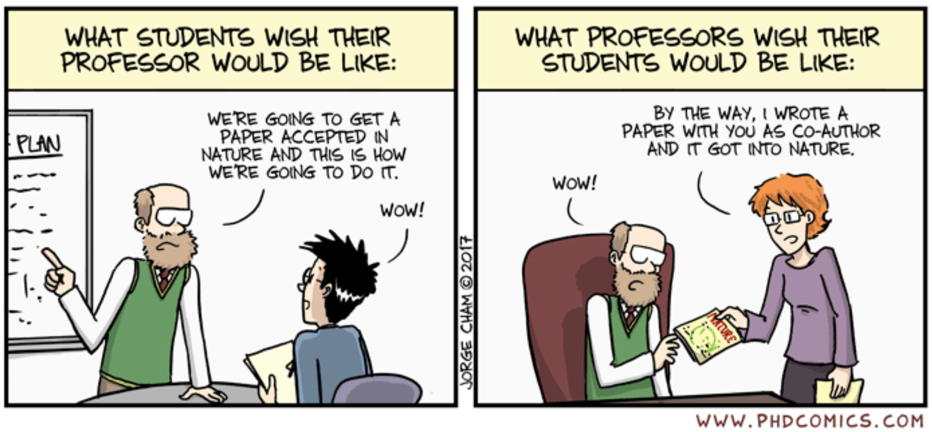
The Graduate School requires that all non-native speakers of English who have not earned their undergraduate degree in a U.S. college or university and who scored below a 27 on the Speaking sub-section of the TOEFL iBT or below an 8.0 on the Speaking sub-section of the IELTS have their oral English proficiency 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 so cannot be reenrolled as a PhD student. A student in this category who is recommended for reenrollment for their second year may be reenrolled as an MSE candidate. PhD candidacy may be reconsidered upon successful completion of the POPT.

3.4 Registration

All students are required to register in August on the date specified by the Graduate School. Students must register for fall and spring term courses by completing course registration through *TigerHub*.

3.4.1 Changing Degree Programs

New graduate students are accepted as PhD, MSE, or MEng students 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 PhD program may transfer from the PhD program to the MSE program to satisfy newly realized goals. Transfer from the PhD program to the MSE program is also possible if the student fails to pass the General Examination for a second time, as outlined in Section 4.1.6, or if the student does not pass the POPT before the end of the first year of study, as outlined in Section 3.3. With the exception of the situation where a student does not pass the POPT before the end of their first year of study, as outlined in Section 3.3, it is not possible to transfer into the PhD program from one of the master's tracks or into the MEng program from either the MSE or PhD track.



4 The PhD, MSE, and MEng Programs

All graduate degree programs draw on the same selection of courses. To remain in good standing, PhD and MSE students must maintain minimum standards for performance in coursework, as described in Section 3.2. 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 PhD Program

The PhD program is typically five years in duration. Formally, a PhD 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 PhD program is designed to prepare a student for independent research, and candidates are expected to demonstrate strong scholarly abilities and the capacity for independent thought.

In consultation with a faculty advisor, a PhD candidate develops an integrated program of courses and research in preparation for the General Examination. Courses from other departments may be suitable for certain students, 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) and performing preliminary research, including over the summer of the first year, in preparation for the General Examination, which is normally taken in January of the second year (see Section 4.1.6). The balance of the program is spent on dissertation research, teaching obligations, and additional courses. All PhD candidates are normally required to serve as Assistants-in-Instruction for a minimum of three half-time appointments or the equivalent (see Section 4.1.9). The culmination of the PhD program is the writing of a dissertation 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 PhD Degree

While the department encourages interdisciplinary research and education, it also recognizes the value of developing competency in a core disciplinary area. The PhD requirements are thus designed to provide students the opportunity to explore both depth within a particular disciplinary area and breath consistent with the student's broader interests. Courses are offered in six departmental disciplines, which currently include: Applied Physics; Biomechanics and Biomaterials; Control, Robotics, and Dynamical Systems; Fluid Mechanics; Materials Sciences; and Propulsion and Energy Sciences.

Students must meet the following requirements to receive the PhD degree:

- Take at least eight (8) courses for a grade prior to standing for the General Examination. All courses must have concrete deliverables such as problem sets, final papers, and/or exams. At least six (6) courses must be taken in the first year of enrollment. Up to two (2) of the eight courses may include MAE 503 ("Directed Research") under the direction of the same or different members of the faculty. These courses must be selected in consultation with the DGS (or another appointed faculty member on the Graduate Committee) and another faculty member within the student's intended research area.
- Take at least one (1) course in mathematics (from the approved list in Section 6.2) prior to standing for the General Examination.

- Participate in two (2) seminar courses during the first year.
- Take at least ten (10) courses 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.
- Pass the General Examination (see Section 4.1.6).
- Complete a minimum of three (3) half-time Assistant-in-Instruction (AI) assignments (or the equivalent), typically after passing the General Examination.
- Complete a written dissertation and pass a Final Public Oral (FPO) presentation of their research.

While a majority of the courses are expected to be graduate-level courses, courses at any level in any discipline can be take with the support of the DGS and the advisor/another faculty member within the student's intended research area. Additionally, with the support of the dissertation advisor and DGS, one (1) pre-generals courses course may be delayed until after the General Examination if not offered beforehand. The course of study and research should be selected so that the PhD program can be completed in no more than five years.

The standard and recommended mathematics course is MAE 501. With prior equivalent graduate-level mathematics coursework, a student can request an exemption from this requirement with a commensurate reduction in required pre-generals courses from eight (8) to seven (7). Students interested in requesting such an exemption should speak with the DGS. Additionally, with the support of the DGS and another faculty member within the student's intended research area, another 500-level mathematics course may substitute for MAE 501 (see Section 6.2 for a list of currently pre-approved courses). Any other courses sequence must be approved by the Department.

In addition to the standard eight-course requirement, all PhD and MSE candidates are required to take EGR 501 in 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.

4.1.2 Advisory Committee for PhD 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 PhD advisory committee for the student, typically referred to as the "PhD committee." The PhD Committee is chaired by the student's thesis advisor and has two additional members. At least one member of the committee must be MAE faculty with the rank of Assistant Professor or higher. 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.

The main duties of the PhD 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 PhD Committee members also serve as examiners in the General Exam discussed in Section 4.1.6.

4.1.3 Pre-Generals Coursework

Students are expected to take eight courses 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, one must be in mathematics, typically MAE 501. The remaining courses are expected to be relevant technical courses. Students usually take four courses in their first semester, and six courses must be taken in the first year. To explore possible research directions, MAE 503, a directed research experience (see Section 4.1.5), may be substituted for two of the eight courses; MAE 503 may be taken with the same or different faculty members. In order to stand for the General Exam, students must achieve an average grade of 3.0 or higher in these courses.

Please note that some courses are offered Pass/D/Fail only. With the exception of MAE 503, all eight pre-generals courses must be taken for a letter grade. If the course is offered Pass/D/Fail, the student must make arrangements with the instructor in advance to receive a letter grade. If these arrangements cannot be made, then the course cannot count as a pre-generals course.

The PhD Committee must verify that these courses meet the pre-generals requirements laid out in Section 4.1.1.

4.1.4 Seminar (MAE 597 and MAE 598)

All first-year students must also participate in the Department seminar course (MAE 597 in the fall and MAE 598 in the spring). This course includes weekly seminars by internal and external speakers on Fridays and a discussion on Mondays led by the faculty host and/or DGS. The weekly discussion may include an assigned paper reading selected by the speaker and the faculty host. First-year students are also encouraged to meet with at least one seminar speaker during the academic year.

4.1.5 Directed Research (MAE 503)

MAE 503 ("Directed Research") 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 presentation in the style of a conference presentation at the end of the semester; the exact format of the presentation (e.g., oral or poster) will be communicated at the beginning of each semester.

Pre-generals students may elect to use MAE 503 as a substitute for up to two of the required eight courses prior to the general exam. MAE 503 may be conducted with same or different faculty members.

Students interested in participating in directed research must enroll in MAE 503 and notify the graduate program administrator at the start of the semester with the name of the faculty that the student is working with and the topic of the project. The student must have the faculty mentor certify successful completion at the end of the term.

4.1.6 The General Examination

The PhD degree in MAE is a certification that the graduating student is well versed in the fundamentals of their 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 PhD 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;
2. To determine the creative potential of the student to conduct PhD level research;
3. To motivate the student to review and synthesize course work and research material; and
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 two components: a "research component" consisting of a 30-minute presentation with an open question period (questions from all audience members) followed by the "subject component," a 90-minute closed question period conducted by the student's PhD committee (see Section 4.1.2). The exam is normally taken in January of the second year. Prior to taking the general examination, students must have satisfied the course requirements described in Section 4.1.3.

Pre-generals PhD Committee meeting. Approximately two months prior to the exam (typically in October or November), the student must meet with the student's PhD Committee. Prior to the meeting, the candidate should prepare a two-page extended abstract of the talk that will be given in the research component of the general exam and send this to the committee members. The candidate should also tell the committee members the eight courses that will have been taken prior to the general exam (see course requirements in Section 4.1.3).

The main objectives of the meeting are as follows:

- To inform the Committee about the research area the candidate is working in and the candidate's progress to date;
- To give the student feedback about the extended abstract and the content of the seminar to be given for the research component; and
- For the Committee to agree on a set of topics the student will be expected to be familiar with for the subject component of the general exam. This could involve specific courses, books, and/or research papers.

Because part of the purpose of the meeting is for the Committee to agree on the topics the student should be familiar with for the subject component, it is important that the entire Committee be present at once; candidates should not meet with different committee members separately.

While the format of the meetings is flexible, below are some suggestions:

- Candidates should give a brief summary of the extended abstract.
- Committee members should ask questions about the research described in the extended abstract and provide feedback to the candidate including general comments about the research direction, advice about the content of the seminar, and any suggestions for revisions to the extended abstract.
- Committee members should discuss and agree on the general topical areas the student should be

expected to know for the subject component of the general exam. This could involve specific courses, books, and/or research papers.

- Committee members should make suggestions about how the student should prepare for the subject component.
- All should agree on a date for the general exam.
- The committee members should fill out and sign the pre-generals PhD Committee meeting form including all of the above information.
- The signed pre-generals PhD Committee meeting form must be turned into the graduate program administrator within one week of the committee meeting.

General Examination. The General Exam is normally conducted in the January of the second year and consists of two components, a research component and a subject component, described below. The examiners are the members of the student's PhD Committee (see Section 4.1.2). The advisor serves as the Chair of the exam and is responsible for ensuring a fair exam. The advisor may ask questions, but the majority of the questions should come from the other examiners. In the case of a re-take of a failed exam, an additional faculty member, typically the Director of Graduate Studies, is present to serve as Chair.

Research component. The research component of the general exam consists of a 30-minute-long public seminar followed by questioning from the faculty and others present. 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 conduct independent research and to organize and communicate technical material and ideas to a relatively general audience. The candidate should demonstrate the following: first, an extensive knowledge of the literature in their field of research; second, the ability to plan, organize, and initiate an independent research project; and, third, 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 PhD.

A ten-minute break should be taken between the research and the subject component of the exam. Before the subject component begins, the advisor (or Chair) will remind the examiners of the types of questions that should be asked, by reading aloud a statement such as the following:

> *"The examiners should favor questions that test the candidate's ability to integrate concepts across courses and apply them to new problems. Questions should not simply test the candidate's ability to recall facts and concepts covered in courses."*

Subject component. The subject component is a 90-minute oral examination 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 in the broader area related to the student's research project. The subject component is not intended to be a collection of superficial questions about the research component nor is it intended to be a summary exam of the graduate course material. Rather, it is an opportunity for the student to demonstrate an ability to synthesize the material from their courses and answer unfamiliar questions. Exam questions should probe the candidate's understanding both of the specific research area and of the broader subject area. The pre-generals course of study should provide adequate preparation to succeed in the subject component of the general exam.

The student may be expected to be conversant in the topics in applied mathematics, for example, topics covered in the MAE 501 and MAE 502 sequence, which are noted below. Specific topics in applied mathematics should be discussed during the pre-generals Committee meeting.

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

Failure Scenarios. It is University and Department policy that students be given two attempts to successfully pass the examination. If a student fails the General Exam, a second attempt must include both research and subject components. For a student's second attempt at the General Exam, in addition to the student's advisor and PhD Committee, an additional faculty member, typically the Director of Graduate Studies, will be present and serve as Chair. It is the Chair's responsibility to ensure a fair exam. A student who fails the exam a second time (usually in May of the second year) is typically 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.

4.1.7 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.

4.1.8 Post-Generals Courses

Post-generals students will be required to take additional courses, at their leisure, so that the total number of courses taken before standing the FPO is at least ten [10]. These additional courses can be taken for a grade or as Pass/D/Fail. This course requirement is independent of the AI requirements. All students are strongly encouraged to continue taking courses beyond the ten-course requirement. Students are also encouraged to enroll in 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.

4.1.9 Assistant in Instruction (AI)

It is a requirement for students to complete a minimum of three (3) half-time AI assignments (or the equivalent) in order to qualify for their PhD. Students may be requested to complete additional AI assignments if there is a Departmental need. 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, half-time AI assignments require approximately ten (10) hours of work per week. First-time AIs will be required to attend the Mandatory AI training in August or January, prior to their AI assignment.

If students with external funding have restrictions on AI assignments, this should be discussed with the Director of Graduate Studies as soon as possible.

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 for AIs to have a clear idea of their responsibilities at the outset of the term. The professor in charge of the course will assign specific duties and normally meets with all of a course's AIs prior to the onset of the semester. Some of the responsibilities AIs may be required to do are listed below:

Attend lectures: Being present at lectures will confirm what AIs need to know for each lecture and will let the students know the AIs 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. Preceptors are responsible for assisting the students to grasp the concepts discussed in the course. The precepts are typically structured to clarify lectures, review problem sets, 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 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. AIs 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, AIs should plan ahead to prepare for the grading of midterms and finals.

Prepare Course Materials and Examinations: Copying, etc. AIs should see the Graduate or Undergraduate Administrator for the code to make copies and/or order desk copies of textbooks. AIs should not order books without first discussing this with the Undergraduate Administrator.

Meetings: Attend all meetings with additional AI members and/or faculty member.

AI Guidelines

The University has guidelines for AI assignments and expects at least two hours of preparation for each hour of classroom contact per week. An AI assignment of "three hours" (or half time) should take the 3 hours of class meeting plus an additional 6–7 hours of work, therefore approximately 10 hours per week. This is a guideline, not a rule, and the requirements vary for different courses. It is important that AIs discuss workload expectations 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 AIs are required to be available for students and faculty during those times. After discussion with the faculty member in charge of the course, any concerns about workload should be discussed with the Director of Graduate Studies.

The McGraw Center for Teaching and Learning provides an online course, on Canvas with a couple hours of interactive modules, followed by a half-day in person workshop at the end of August (for the fall semester) and January (for the spring semester). All new AIs are required to attend.

4.1.10 The PhD Dissertation

A PhD 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 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.

Although a dissertation may present results from collaborative efforts, the dissertation itself must have only a single author. A simple gathering of previously published or co-authored papers does not constitute a PhD dissertation and will not be accepted. If a PhD candidate has written or co-authored papers that have already been published or submitted for publication, these may be included in an appendix or a separate section, but the main body of the dissertation must still contain a complete, self-contained description of the work. 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 PhD 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 PhD 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, PhD degree candidacy terminates five (5) years after the date of passing the General Examination. If a student presents a dissertation for the PhD 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 PhD 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 PhD dissertation are favorable, the final version of the dissertation should be prepared. Full information about the required format can be found at the Princeton University Seely G. Mudd Manuscript Library website rbsc.princeton.edu/services/theses-dissertations.

The abstract, in 12-point type, may not exceed 350 words. 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 pdf copy of the final dissertation shall be submitted to the MAE Graduate Office for reading by the faculty. 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 PhD 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 PhD degree. If at least two of the three reports recommend positive action on the thesis, one pdf copy of the thesis should be submitted to 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.

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 is responsible to review the Graduate School website (gradschool.princeton.edu/academics/degree-requirements/phd-advising-and-requirements/dissertation-and-fpo/advanced-degree).

The student should complete the Checkout Form for Students Departing the University, which can be accessed in TigerHub under the Enrollment and Graduation Tile.

PhD 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; dates can be found on the Graduate School website: gradschool.princeton.edu/academics/degree-deadlines.

4.1.10.A 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:

1. A lecture of about 45 minutes by the candidate on the candidate's research. Faculty, students, and the public are invited to attend.
2. Questions by the designated examiners.
3. 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 one of the three examiners must be a current regular MAE faculty member. 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 PhD 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.

For more information, see gradschool.princeton.edu/academics/degree-requirements/phd-advising-and-requirements/dissertation-and-fpo/advanced-degree.

4.1.11 Internships (MAE 515 and MAE 595)

For students wishing to pursue full-time opportunities external to the University, this should be discussed first with the advisor and then with the Director of Graduate Studies. The Graduate Program Administrator will advise on the necessary administrative steps required to process a formal request for an internship. International students should also contact the Davis International Center for information about visas and Curricular Practical Training (CPT). As appropriate, students pursuing summer internships can enroll in MAE 515, and students pursuing academic year internships can enroll in MAE 595. Neither MAE 515 nor MAE 595 satisfy the post-generals course requirement. Note that internships during the academic year are restricted to post-generals students; a draft paper reporting on the research during an academic year internship is required at the end of the academic year and should be a draft of material to be included in the dissertation.

4.2 Master of Science in Engineering (MSE) Program

The Master of Science in Engineering program is of two years duration and includes an original thesis. MSE candidates are required to take at least eight courses in addition to writing a thesis, which demonstrates their mastery of selected technical areas. MSE students do not normally take MAE 503 ("Directed Research") and need department approval to do so. All eight courses, with the exception of MAE 503, must be taken for a grade.

4.2.1 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 "C" average level or better in a minimum of eight courses taken for a grade selected in consultation with the faculty advisor, and submit an acceptable thesis. The Director of Graduate Studies must approve all programs. A thesis is required of each Master's candidate and is the culmination of the 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 adequate 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 "C".

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. 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 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 Office if a response from the advisor or the reader is not made within this time limitation.

One final copy of the thesis must be submitted to the MAE Graduate Office for reading by the Departmental faculty. The availability of the thesis for reading by the faculty will be announced promptly in a memorandum, 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." Information about the required format for the thesis may be found here: 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.

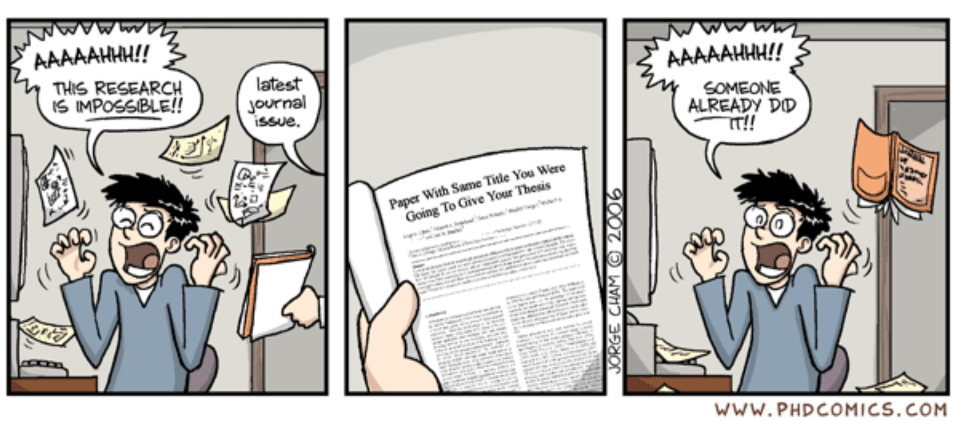
A student is normally expected to complete research for an MSE thesis while in residence. The Department discourages theses being written in absentia, except under special circumstances, e.g., the need to use facilities not available at Princeton. Students anticipating the need to complete a thesis in 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.

4.3 Master of Engineering (MEng) Program

The Master of Engineering (MEng) program is particularly suited to those interested either in obtaining a more fundamental understanding of their field or in broadening their experiences to include disciplines outside of their particular technical focus areas. The MEng degree is a coursework-based degree with no research or thesis requirement. Candidates for the MEng degree will normally satisfy degree requirements within one (10-month) academic year.

Candidates for the MEng degree must successfully complete eight (8) graduate courses. Six of these courses must be technical with no more than two being independent projects. A minimum of four of the technical courses must be taken in the Department. For candidates who earned an undergraduate degree at the University, none of the eight courses may be courses that were also taken as part of that undergraduate degree program. To qualify for the MEng degree, the eight courses must be taken for a grade (with the exception of independent project courses) and passed with at least a 3.0 or “B” average with no more than one “C” grade permitted to count towards the eight courses.

The MEng degree program is intended to be individualized and as unconstrained as possible, and a coherent program of study is developed in consultation with a faculty advisor. Opportunities for study exist within the various research areas of the Department including Applied Physics; Biomechanics and Biomaterials; Controls, Robotics, and Dynamical Systems; Fluid Mechanics; Materials Science; and Propulsion and Energy Sciences.



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 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.

5.2 MAE Graduate Student Vacation Policy

Departmental vacation policy is consistent with the Graduate School policy (gradschool.princeton.edu/policies/student-vacation-time):

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, August 1 to May 31), 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, August 1 to May 31, then that student should not take additional vacation time during the summer months of June and July.

If a student holds an external fellowship whose terms may conflict with this policy, the student should consult first with the director of graduate studies or adviser.

5.3 Office Space, Keys to Laboratories, Mailbox

First-year students will be assigned office desk space. Any questions should be directed to the MAE Graduate Office. When the student arrives, the student will have a mailbox in the MAE mailroom. Laboratory keys can be obtained in the MAE Department Office (D209).

5.4 Department 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*, and 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 and the *Larisse Rosentweig Klein Prize* recognizes a female student in the third year or beyond who has shown exemplary research capability.

The Graduate School also offers Honorific Fellowships, and each year the department nominates up to three top students entering their final dissertation year for this award.

5.5 Outside Fellowships

MAE encourages students to apply for outside fellowships. Please see the Graduate School's policy regarding external fellowships, found here: gradschool.princeton.edu/policies/external-fellowships.

6 Departmental Graduate Courses

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. The first part of the course covers complex variables, including power series, contour integration, Cauchy's theorems, and Fourier series. The remainder of the course covers topics in functional analysis, including an introduction to measure theory and the Lebesgue integral, Hilbert spaces and Banach spaces, linear operators and their spectral properties.

503 (Directed Research): Under the direction of a faculty member, the student carries out a one-semester research project chosen jointly by the student and the faculty. Directed is normally taken during the first year of study. The project culminates in a written paper, in the style of a journal article, and presentation to at least one faculty member from the department who was involved in the research project. Students need to enroll at the beginning of the semester and must obtain permission from the instructor and the department.

506 (APC 524, Software Engineering for Scientific Computing): The goal of this course is to teach basic tools and principles of writing good code, in the context of scientific computing. Specific topics include an overview of relevant compiled and interpreted languages, build tools and source managers, design patterns, design of interfaces, debugging and testing, profiling and improving performance, portability, and an introduction to parallel computing in both shared memory and distributed memory environments. The focus is on writing code that is easy to maintain and share with others. Students will develop these skills through a series of programming assignments and a group project.

507 (APC 523, Numerical Algorithms for Scientific Computing): A broad introduction to numerical algorithms used in scientific computing. The course will begin with a review of the basic principles of numerical analysis, including sources of error, stability and convergence of algorithms. The theory and implementation of techniques for linear and nonlinear systems of equations, and ordinary and partial differential equations will be covered in detail. Examples of the application of these methods to problems in physics, astrophysics and other disciplines will be given. Issues related to the implementation of efficient algorithms on modern high-performance computing systems will be discussed.

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, not currently offered): 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 receive 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.

516 (Bioinspired Design): This bioinspired design course offers interdisciplinary, advanced design and critical thinking experience. Students work in teams to integrate biological knowledge into the engineering design process. The course uses case studies to show how biological solutions can be transferred into engineering design. The case studies include themes such as locomotion, materials, and sensing. By the end of the course, students are able to use analogical design concepts to engineer a prototype based on biological function.

517 (CBE 517, Soft Matter Mechanics: Fundamentals & Applications) We cover fundamental aspects of the mechanics of soft matter and see how they provide useful insights about novel engineering designs and materials (3D printing, soft robotics, metamaterials). Particular attention is given to interfacial effects, which dominate the physics of small objects. Topics include, drops, bubbles, wetting, coatings, instabilities. We also cover the mechanics of thin elastic objects whose deformability characterizes many biological systems. Students learn how to build quantitative physical models, combining experimental observations, scaling analysis and formal approaches.

518 (Virtual and Augmented Reality for Scientists, Engineers, and Architects): VR/AR can enable engineers, scientists, and architects to plan and conduct their work in fundamentally new ways, visualize and communicate their findings more effectively, and work in environments that are otherwise difficult, impossible, or too costly to experience in person. This course explores the basic concepts of effective VR/AR experiences and builds the skills needed to develop and support innovative science, engineering, or architecture projects. In the second half of the semester, working in small teams, students develop and implement VR/AR projects of their choice.

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): The course introduces laser essentials, Fourier optics, optical pulses, and laser diagnostics through lectures and practical exercises. Topics include ray optics, wave optics, optical Fourier transform, schlieren imaging, ultrafast optics and material dispersion. Optical component kits are provided for practical exercises aimed at the design and construction of an optical system to focus, collimate, and expand light beams with convex lenses, observe aberrations, perform imaging, study diffraction patterns in the rear focal plane of a convex lens, manipulate light in the Fourier domain, and use schlieren technique to visualize air flows.

522 (AST 564, Applications of Quantum Mechanics to Spectroscopy and Lasers, not currently offered): 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.

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, magnetoplasmadynamic 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): Chemical thermodynamics and kinetics, oxidation of hydrogen, hydrocarbons and alternate fuels, pollutant chemistry and control, transport phenomena, laminar premixed and non-premixed flames, turbulent flames, ignition, extinction, and flammability phenomena, flame stabilization and blowoff, detonation and blast waves, droplet, spray and coal particle combustion, principles of engine operation.

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.

534 (Energy Storage Systems): This is a survey course on energy storage systems with a focus on electrochemical energy storage. Fundamentals of thermodynamics will be reviewed and fundamentals of electrochemistry introduced. These fundamentals will then be applied to devices such as batteries, flywheels and compressed air storage. Device optimization with respect to energy density, power density, cycle life and capital cost will be considered.

535 (Turbulent Reacting Flows): Detailed treatment of the physics and modeling of turbulent combustion. Turbulent premixed, nonpremixed, and partially premixed combustion are all discussed. Emphasis in the course is placed on understanding relevant physical and chemical phenomena that lead to various modeling approaches (derived from both experiment and computation), the implicit and explicit assumptions in these modeling approaches, and the relative strengths and weaknesses of these modeling approaches.

536 (MSE 586, Synchrotron and Neutron Techniques for Energy Materials): Topics include an introduction to radiation generation at synchrotron and neutron facilities, elastic scattering techniques, inelastic scattering techniques, imaging and spectroscopy. Specific techniques include X-ray and neutron diffraction, small-angle scattering, inelastic neutron scattering, reflectometry, tomography, microscopy, and X-ray absorption spectroscopy. Emphasis is placed on data analysis and use of Fourier transforms to relate structure/dynamics to experiment data. Example materials covered include energy storage devices, sustainable concrete, CO2 storage, magnetic materials, mesostructured materials and nanoparticles.

538 (Electrochemical Engineering): This course goes over the fundamental electrochemistry in applied systems related to batteries, fuel cell, electrochemical fuel production, and supercapacitors. The class covers thermodynamics, kinetics, and transport related topics as they pertain to electrochemical system. The context of this class overlaps with fundamental principles taught in chemical engineering, material science, mechanical engineering, and electrical engineering. The class has several hands-on laboratory exercises to review electrochemical characterization techniques: electrochemical impedance spectroscopy, chronoamperometry, galvanostatic cycling, cyclic voltammetry.

539, 540 (Advanced Topics in Combustion I, II): Selected topics in theoretical, experimental, and computational combustion, with an emphasis on advances relevant to research activities represented in the department. Possible topics include turbulent combustion, advanced chemical kinetics, theoretical calculations of rate-constants, and plasma-assisted combustion.

541 (APC 571, Applied Dynamical Systems, offered in alternate years): 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.

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 Mechanics, offered in alternate years): 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.

544 (Nonlinear Control, not offered every year): 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.

545 (Special Topics in Mechanical & Aerospace Engineering): Topics vary.

546 (Optimal Control): The course covers parameter optimization, aspects of the calculus of variations, and the conditions of Pontryagin's principle and dynamic programming for optimal control of deterministic dynamical systems. Numerical methods for solution of the optimal control problem are covered with applications. The course provides a concise review of relevant tools from probability and stochastic calculus to enable similar statements on conditions for optimality of stochastic dynamical systems. Emphasis is placed on drawing connections and intuition between the various aspects of the course.

547 (ECE 521, 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 (ECE 523, Nonlinear System Theory, offered in alternate years): 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.

549 (Introduction to Robotics): Robotics is a rapidly-growing field with applications including unmanned aerial vehicles, autonomous cars, and robotic manipulators. This course provides an introduction to the basic theoretical and algorithmic principles behind robotic systems. The course also allows students to get hands-on experience through project-based assignments on quadrotors. In the final project, students implement a vision-based obstacle avoidance controller for a quadrotor. Topics include motion planning, control, localization, mapping, and vision.

550 (Lessons from Biology for Engineering Tiny Devices): In this course we present a survey of problems at the interface of biology, physics and engineering to discuss how nature invented many tiny sensors, machines and structures that are important for functions of cells and organisms. Using this knowledge, we comment how to engineer and self-assemble tiny devices with DNA origami, how to design thin structures that can transform into specific shapes in response to external stimulus, how to make structures with tunable surface properties (drag, adhesion, hydrophobicity/hydrophilicity), how to make flexible electronics, how to make metamaterials with unusual properties, etc.

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): Non-Continuum description of transport and reacting flow. The course examines molecular collisions, Boltzmann equation, and Chapman-Enskog theory for near-equilibrium transport and flows as well as elementary chemical kinetics, non-equilibrium rarefied gas flow, radiation, and shock wave structure.

557 (Simulation and Modeling of Fluid Flows): Overview and fundamentals of numerical algorithms and models for computational fluid dynamics. Numerical approaches discussed include finite difference, finite volume, finite element, and spectral methods on both structured and unstructured grids. Coverage includes asymptotically zero Mach number (incompressible), low-speed compressible, and high-speed compressible flows. Introduction to a varying modeling topic such as turbulence modeling or multi-phase flow modeling.

559 (Advanced Topics in Fluid Mechanics): 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, not currently offered): 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.

563 (Instabilities in Fluids: Linear and Non-Linear Analysis of Waves and Patterns in the Environment): This course describes natural patterns arising from instabilities in nature, and discusses their importance in the environment. We analyze phenomena at various scales, as diverse as wave breaking at the ocean surface, internal mixing in the atmosphere and the ocean, volcanic plumes, convection cells in the atmosphere, the break-up of fluid ligaments or bubble bursting at an interface. The course details mathematical tools (linear and non-linear stability analysis, symmetry arguments, solutions to non-linear equations such as shocks and solitons), as well as present laboratory and numerical demonstration of the instabilities.

564 (MSE 512, Structural Materials, offered in alternate years): 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.

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 (Biomechanics and Biomaterials: From Cells to Organisms): Bioengineering is proof that exciting developments happen at the interfaces between fields. This course introduces students to approaches spanning biomechanics and biophysics, biomaterials and tissue engineering, and biomedical device design. These approaches are explored in the context of single cells, tissues, and whole organisms. Sample topics include: mechanobiology, surface chemistry and the cell:material interface, the biomechanics of locomotion, and "lab on a chip"technologies. Special emphasis is placed on introducing practical biomedical examples from the bench to the operating room.

567 (CBE 568, Crowd Control: Understanding and Manipulating Collective Behaviors and Swarm Dynamics): Collective behaviors are all around us, from bird flocking, to mosh pit dynamics, to how the cells in our bodies work together. In this course, we explore not only how to understand and quantify these behaviors, but also how we can start to engineer them to reduce traffic, heal faster, develop new materials, and introduce new robotics approaches. The course spans three modules: hands-on training in analyzing real-world swarming systems; fundamental concepts underlying collective behaviors; and key case studies in manipulating these systems.

568 (MSE 568, Energy Transport at the Nanoscale): This course covers fundamental and applied aspects of energy transport in nanoscale materials and devices. Basic concepts in solid-state physics and quantum mechanics are synthesized with contemporary theories of molecular, electron, photon, and phonon (vibrational) transport, to build a holistic picture of energy dissipation across length scales. Topics include thermal conduction, scattering, sub-continuum transport, nanoscale thermometry, and thermoelectricity geared towards understanding key technologies in nano-electronics, energy harvesting, sensors, and MEMS.

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.

571 (Inspiring Young Engineers through Outreach, not offered every year): We study effective ways to inspire young students to think about science and engineering. Four concepts of modern engineering are identified and demonstration labs are built around them. The setups are built using modern yet simple tools and are accompanied by a video explaining how the concepts fit together in a larger picture. A field trip is made to a science exhibition to study methods to inspire and teach science to young people. At the end of the course the students perform demonstrations to students from Harlem Prep Elementary who will visit the MAE department.

573 (ENE 539, Applied Optimization for Energy Systems Engineering): In this course students learn practical applications of optimization methods in energy systems engineering. Students also gain familiarity with techniques via survey of canonical problems in power systems operations and planning. The course teaches practical model development, including formulation and implementation of linear and mixed integer programs in an algebraic programming language. The second half surveys advanced topics, including: managing dimensionality in large-scale problems, technology evaluation, policy evaluation, decision making under uncertainty, and multi-objective optimization.

574 (Unmaking the Bomb, not offered every year): This course covers the science and technology underlying existing and emerging nuclear security issues. It introduces the principles of nuclear fission, nuclear radiation, and nuclear weapons (and their effects) and develops the concepts required to model and analyze nuclear systems. The second half of the semester is centered around a hands-on team project.

575 (Data Assimilation): This course covers the theory and numerical algorithms of nonlinear filtering and smoothing, starting with the discrete-time linear Gaussian case and advancing through the general continuous-time nonlinear non-Gaussian case. Variants of Kalman and ensemble methods will be covered with derivations and sketches of important proofs. A review of the necessary elements from probability and stochastic processes will be included. Following the theory, numerical algorithms will be regularly demonstrated on a suite of problems that include aerospace and geoscience applications.

577 (Multi-Robot Systems: Body-Brain-Colony): Most applications of robotics envision many robots cooperating together to achieve similar benefits, whether it be warehouses, or environmental monitoring, or construction, or future space exploration. In this seminar-research style class, we study the hardware, software, and communication design of multi-robot systems.

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.

595 (Extramural Research Project): A research project designed in conjunction with the student's advisor and an industrial, NGO, or government sponsor that provides practical experience relevant to the student's thesis topic. The full- time research project is conducted at the host institution. A final paper is required. Enrollment is limited to post-Generals students and requires the support of both the student's advisor and the Director of Graduate Studies. The course does not count toward the post-Generals course requirement.

597, 598 (Graduate Seminar in Mechanical and Aerospace Engineering): A seminar of internal and external speakers on a diverse range of topics relevant to Mechanical and Aerospace Engineering including Applied Physics; Biomechanics and Biomaterials; Control, Robotics, and Dynamical Systems; Fluid Mechanics; Materials Science; and Propulsion and Energy Sciences. There is one seminar per week on Friday and a subsequent discussion on Monday. All first-year PhD students are required to participate.

6.1 Courses Offered in Each Departmental Discipline

Asterisks (**) indicate foundational courses in each discipline

6.1.1 Applied Physics

- 521 Optics and Lasers **
- 522, AST564 Applications of Quantum Mechanics to Spectroscopy and Lasers
- 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
- AST 552 General Plasma Physics II
- AST 553 Plasma Waves and Instabilities
- AST 554 Irreversible Processes in Plasmas
- AST 559 Turbulence in Plasma
- AST 560 Computational Methods in Plasma Physics
- AST 562 Laboratory in Plasma Physics
- PHY 501 Electricity and Magnetism
- PHY 505 Quantum Mechanics I
- PHY 511 Thermodynamics, Kinetic Theory & Stat Mechanics
- CHM 501 Introduction to Quantum Chemistry
- CHM 502 Advanced Quantum Chemistry
- CHM 503 Introduction to Statistical Mechanics
- CHM 504 Molecular Spectroscopy
- CHM 509, 510 Topics in Physical Chemistry
- CHM 512 Chemical Kinetics

6.1.2 Biomechanics and Biomaterials

- 566 Biomechanics and Biomaterials: From Cells to Organisms **
- 567 Crowd Control: Understanding and Manipulating Collective Behaviors and Swarm Dynamics
- 519 Experimental Methods in Engineering

- 550 Lessons from Biology for Engineering Tiny Devices
- 512 Phase Transformations in Materials: Theory and Simulation

6.1.3 Controls, Robotics, and Dynamical Systems

- 433 Automatic Control Systems **
- 434 Modern Control **
- 541, APC 571 Applied Dynamical Systems
- 542 Advanced Dynamics **
- 543 Advanced Orbital Mechanics
- 544 Nonlinear Control
- 546 Optimal Control **
- 547, ECE 521 Linear System Theory
- 548, ECE 523 Nonlinear System Theory
- 549 Introduction to Robotics
- 566 Biomechanics and Biomaterials: From Cells to Organisms
- 575 Data Assimilation
- 577 Multi-Robot Systems: Body-Brain-Colony

6.1.4 Fluid Mechanics

- 527 Physics of Gases
- 539 Advanced Topics in Combustion I: Turbulent Combustion
- 551 Fluid Mechanics **
- 552 Viscous Flows and Boundary Layers **
- 553 Turbulent Flow
- 555 Non-Equilibrium Gas Dynamics
- 557 Simulation and Modeling of Fluid Flows
- 559 Advanced Topics in Fluid Mechanics
- AOS 571 Introduction to Geophysical Fluid Dynamics
- AOS 573 Physical Oceanography
- AST 523, APC 523 Scientific Computation in Astrophysics
- CBE533, MSE 523 Introduction to the Mechanics and Dynamics of Soft Living Matter

6.1.5 Materials Sciences

- MSE 452 Phase Transformations and Evolving Microstructures **

- 534 Energy Storage Systems
- 536 Synchrotron and Neutron Techniques for Energy Materials
- 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
- 566 Biomechanics and Biomaterials: From Cells to Organisms
- 569, 570 Advanced Topics in Materials and Mechanical Systems I, II
- MSE 505 Characterization of Materials **
- MSE 513, CHM 511 Introduction to Nanotechnology
- ECE 553, MSE 553 Nonlinear Optics
- ECE 441 Solid State Physics I
- ECE 442 Solid State Physics II
- ECE 449 Materials and Solid-State Device Laboratory
- ECE 453 Optical Electronics
- CBE 517, MAE 517 Soft Matter Mechanics: Fundamentals & Applications
- CBE 526, CHM527, MSE526 Surface Science: Processes and Probes
- CEE 513 Introduction to Finite Element Methods
- CEE 521 Continuum Mechanics
- CHM 501 Introduction to Quantum Chemistry
- CHM 503 Introduction to Statistical Mechanics

6.1.6 Propulsion and Energy Sciences

- 527 Physics of Gases *
- 531 Combustion **
- 532 Combustion Theory
- 535 Turbulent Reacting Flows
- 539, 540 Advanced Topics in Combustion I, II
- 551 Fluid Mechanics **
- 552 Viscous Flows and Boundary Layers
- 553 Turbulent Flows
- 555 Non-Equilibrium Gas Dynamics *
- 579, 580 Advanced Topics in Energy and Environment I, II

- 580, SPIS585b Living in a Greenhouse: Technology and Policy

6.2 Pre-approved Math Courses

- MAE 501 Mathematical Methods of Engineering Analysis I (standard)
- MAE 502 Mathematical Methods of Engineering Analysis II
- ECE 535 Machine Learning and Pattern Recognition
- ORF 523 Convex and Conic Optimization
- ORF 524 Statistical Theory and Methods
- ORF 526 Probability Theory
- ORF 527 Stochastic Calculus

7 Travel Policy, Booking, and Reimbursement

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

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:

- travel.princeton.edu/graduate-students/graduate-travel-policies

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.

All travel booking and expense reimbursements will be done in the online system Concur. 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.

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. Check the student links on the Travel & Expense website to guide you through this process. A few highlights about this travel and expense processes:

- Paper receipts are not required. Pictures and scans of receipts must be legible.
- Per diem will not be accepted. You must provide actual detailed receipts for meals and incidentals. Credit card receipts are not a sufficient substitute for the detailed receipt.
- 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 MAE website: mae.princeton.edu/about-mae/administrative-offices/doing-research-mae and click on “Travel” under “Proposal Submission.”

8 Important Campus Contacts

Public Safety, Emergency: (609) 258-3333 or 911

Public Safety, General Information: (609) 258-1000

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

Counseling and Psychological Services Emergency: (609) 258-3139

Davis International Center: (609) 258-5006

Graduate Housing Office: (609) 258-3460

LGBT Center: (609) 258-1353

Office of Disability Services: (609) 258-8840

Ombud's Office: (609) 258-1775

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

University Health Services: (609) 258-3141

Women's Center: (609) 258-5565

Cartoons by Jorge Cham, www.phdcomics.com, author of *Piled Higher and Deeper* and
We Have No Idea: A Guide to the Unknown Universe (with Daniel Whiteson); used with permission

The equity-and-inclusion statement reproduced in Section 2 is based on language first developed by Princeton's Department of Chemistry and is used with permission here

Special thanks go to Meredith A. LaSalle-Tarantin, Susan VanderKam, and Robert L'Esperance