Mechanical Engineering Graduate Master Document

Rutgers University

Introduction

The graduate program in Mechanical and Aerospace Engineering offers the degrees of M.Eng., M.S. and Ph.D. in an intellectually and academically stimulating environment. Our program takes pride in the collegial student-faculty relationship it provides and in its preparation of students for successful careers in industry, government and academia.

Our current enrollment is about 180 graduate students. About 90% of our graduate students are enrolled on a full-time basis. Most of our full-time graduate students are supported by teaching or research assistantships, as well as by fellowships. To accommodate the needs of our part-time students, who mostly work in local industry, each semester a few of our graduate courses are taught in the evenings.

We have 28 internationally renowned faculty members in residence, who teach and conduct research on a broad range of topics. We loosely group the departmental research under the following banners: Design and Control; Solid Mechanics, Materials and Structures; Fluid Mechanics; and Thermal Sciences. In addition, several distinguished colleagues from other departments are affiliated with our graduate program.

Rutgers is conveniently located in central New Jersey, with an abundance of social, cultural and recreational facilities. New York and Philadelphia are easily accessible by car, train or bus.

The Rutgers MAE offers several degrees in graduate studies and they are the following:

Degrees Offered

Master of Engineering

The Master of Engineering degree in Mechanical and Aerospace Engineering is a terminal professional degree, designed primarily for professionals working in industry or government. The program requires the completion of 30 course credits and a project. A final oral examination and report based on the project is required. Specifics are delineated below.

- Of the required 30 course credits, a minimum of **seven** 3 credit courses **must** be M&AE (650) graduate courses.

- Candidates are expected to earn grades of B or better in their coursework to be in good standing. A 3.0 GPA must be maintained throughout the course of study. A student whose grade point average falls below 3.0 will be dropped from the graduate program.

- No more than three credits with grades C or C+ may be used in meeting the 30 credit course requirement.

- *At the discretion of the Graduate Program Director*, up to two undergraduate courses (6 credits) may be counted toward the course requirements. The courses must be at the 400

level. A graduate student who wishes to register for an undergraduate course **must** have the approval of the Graduate Program Director.

- A student in the M.Eng. Program may register for, at most, one (3 credit) Independent Study course (650:601 or 602).

- Must register for Methods of Applied Mathematics (642:527)

- The final exam will consist of a written report based on the project, and a presentation of the report to a faculty committee via a public forum. The project can be the result of a three credit independent study that the student can opt for. An advisor from the graduate faculty in Mechanical and Aerospace Engineering will supervise the project. The project can be related to an engineering problem that the student is involved in at the workplace.

The program offers several broad areas of specialization. These include (1) Design and Control; (2) Fluid Mechanics; (3) Mechanics of Solids, Materials and Structures; and (4) Thermal Sciences. The M.Eng. program, however, allows and encourages a student to include in his/her program of study related courses from any of the areas of specialization and also relevant courses offered by other programs within the Graduate School.

The M.Eng. program assumes that the student's preparation in applied mathematics is equivalent to that covered in a course on advanced calculus equivalent to 640:421. A student whose background does not include this material should take 640:421, or an equivalent course, before taking 640:527. The program also assumes that the student has a working knowledge of scientific programming languages such as MATLAB, MAPLE, FORTRAN and C. A student whose background does not include computer programming may take 650:231, or an equivalent course, on a non-credit basis.

Students who have nearly completed their program of study, including should notify the Graduate Program Director by completing the forms entitled "*Application for Admission to Candidacy*" and the *Graduate Diploma Application*. These forms are available from the Graduate Secretary in Room B-226

Master of Science

The requirements for the Master of Science degree include the completion of 24 course credits, 6 research credits, and the writing of and successful public defense of a thesis.

- Of the required 24 course credits, a minimum of **five** 3 credit courses **must** be M&AE (650) graduate courses.

- Candidates are expected to earn grades of B or better in their coursework to be in good standing. A 3.0 grade point average (GPA) must be maintained throughout the course of study. A student whose GPA falls below 3.0 will be dropped from the graduate program.

- No more than three credits with grades C or C+ may be used in meeting the 24 credit course requirement.

- Must register for Methods of Applied Mathematics (642:527)

- *At the discretion of the Graduate Program Director*, up to two undergraduate courses (6 credits) may be counted toward the course requirements. The courses must be at the 400 level. A graduate student who wishes to register for an undergraduate course **must** have the approval of the Graduate Program Director.

- A student in the M.S. program may register for, at most, one (3 credit) Independent Study course (650:601 or 602).

The program offers several broad areas of specialization. These include (1) Design and Control; (2) Fluid Mechanics; (3) Mechanics of Solids, Materials and Structures; and (4) Thermal Sciences. The M.S. program, however, allows and encourages a student to include in his/her program of study related courses from any of the areas of specialization and also relevant courses offered by other programs within the Graduate School.

The M.S. program assumes that the student's preparation in applied mathematics is equivalent to that covered in a course on advanced calculus equivalent to 640:421. A student whose background does not include this material should take 640:421, or an equivalent course, before taking 640:527. The program also assumes that the student has a working knowledge of scientific programming languages such as MATLAB, MAPLE, FORTRAN and C. A student whose background does not include computer programming may take 650:231, or an equivalent course, on a non-credit basis.

A semester or so before the anticipated date for completion of the M.S. degree, the student should meet with the Graduate Program Director and confirm that the student has met (or will meet) all graduation requirements. A checklist is provided below.

- After the research has been completed under the supervision of a member of the Graduate Faculty of Mechanical and Aerospace Engineering, a thesis is written in accordance with

the guidelines set forth in the booklet "*Style Guide for Thesis Preparation"* (available from the Graduate Secretary (B226) or the Graduate School).

- When the thesis advisor approves it, he/she will notify the Graduate Program Director who will, in turn, appoint two additional faculty members as *readers* of the thesis. The readers, together with the advisor, will serve as members of the student's "Thesis Examination Committee". After each member of the committee reads the thesis and approves proceeding forward, the Graduate Program Director will schedule a final oral thesis defense in a **public** forum.

- Students who have nearly completed their program of study, including the writing of the thesis, should notify the Graduate Program Director by completing the forms entitled "*Application for Admission to Candidacy*" and the *Graduate Diploma Application*. These forms are available from the Graduate Secretary in Room B-226.

Ph. D.

A. General Requirements

A student enrolled in the M.S. program must obtain permission to study towards a Ph.D. degree. Application forms for this purpose are available from the Graduate Program Office. This application must be made at least one month before the completion of the M.S. degree requirements.

- The doctoral student is expected to complete at least 48 credits of course work (beyond the bachelor's degree) and at least 24 credits of research work.

  A student who started in the department with a B.S. degree must take a minimum of 10 MAE courses. A student who started in the department with an M.S. degree must take a minimum of six (6) MAE courses.

  No more than 6 credits with grades C or C+ maybe used in meeting the 48 credit course requirement.

  A student in the Ph.D. program may register for one Independent Study course (in addition to the one he/she may have taken at the M.S. level).

  A student in the Ph.D. program can take a maximum of 6 undergraduate course credits. Included in this maximum are any undergraduate course credits the student accumulated while in the M.S. program. The undergraduate courses must be at the 400 level and they must be approved by the graduate program director.

  Students in the Ph.D. program may transfer up to 24 course credits from another institution Click here for more details.

  All students must take the two Applied Mathematics Courses (642:527 and 642:528) and at least one graduate level course from each of the following four areas:

Design and Control
Fluid Mechanics
Solid Mechanics, Materials and Structures
Thermal Processes

  Courses are classified according to areas in the section Descriptions of Graduate Courses.

  Transferred course credits can be counted for these minimum MAE course requirements.
- At least one year of full-time residence is required for the Ph.D. While the student may be a full-time student throughout his/her studies, the one-year residence requirement is normally satisfied after the student has passed the qualifying examination and is mainly

devoted to research activities. This residency permits the student to benefit from interactions with the faculty and other students of the Department, College and University.

- When the full-time doctoral student has completed (or is near completion) two academic years of full-time graduate work past the B.S. degree, he/she is generally prepared to take the qualifying examination.
- Prior to taking the qualifying examination, a doctoral student should take a number of required courses that depend on the area of specialization. At present, the program offers four areas: (1) Design and Control, (2) Fluid Mechanics, (3) Solid Mechanics, Materials and Structures, and (4) Thermal Processes. While it is not mandatory that the student take these courses, we strongly recommend that the student do so. Some students may have taken these courses in their prior academic institution. The recommended courses are listed below.

Design and Control	**Fluid Mechanics**
Methods of Applied Mathematics, 642:527, 528	Methods of Applied Mathematics, 642:527, 528
Design of Mechanisms, 650:514, Analytical Dynamics, 650:522	Fluid Mechanics I and II, 650:530, 630
Mechanics of Materials, 650:550	Conduction Heat Transfer, 650:570
Optimal Design in Mechanical Engineering, 650:614	Thermodynamic Theory, 650:574
Total Credits: 18	**Total Credits: 18**
Solid Mechanics, Materials and Structures	**Thermal Processes**
Methods of Applied Mathematics, 642:527, 528	Methods of Applied Mathematics, 642:527, 528
Analytical Dynamics, 650:522	Fluid Mechanics I, 650:530
Mechanics of Materials, 650:550	Conduction Heat Transfer, 650:570
Mechanics of Continua (Solid Mechanics I), 650:554	Thermodynamic Theory, 650:574
Theory of Elasticity (Solid Mechanics II), 650:556	Convection Heat Transfer, 650:578
Total Credits: 18	**Total Credits: 18**

B. Qualifying Examination

Every doctoral student must take the Qualifying Examination in order to be admitted into candidacy. The following general rules apply:

- The qualifying examination is to be taken at the end of the first year of full time study by students entering the Ph.D. program with a Master's degree, and no later than the end of the second year by students entering the program with a Bachelor's degree.
- Qualifying examinations are usually held in May, after the final examinations and before Commencement Day.
  A doctoral student is not permitted to take the qualifying examination if he/she is not making satisfactory progress or if his/her cumulative average of all courses taken at Rutgers since matriculation into the Graduate School is lower than B. A student wishing to take the qualifying examination should apply in writing to the Graduate Director for permission to take the examination. Early in the spring semester, an announcement is set to all graduate students regarding the qualifying examination. Students wishing to take the

qualifying exam should respond to that announcement with a letter that includes a detailed statement showing how the course recommendations have been acted upon.

- A student whose application to take the examination is granted should complete Part I of the form Application for Admission to Candidacy for the Degree of Doctor of Philosophy, and submit it to the chairperson of the examination committee prior to the examination. The Ph.D. Qualifying Examination Committee consists of four members, one for each of the four major areas of concentration. A fifth member, usually from the Mathematics Department, may be added to the committee.
- The type, content and duration of the Qualifying Examination are at the discretion of the Examination Committee and the Graduate Director. The normal format, however, consists of a written and sometimes an oral part, as described below.

Written Part

1. The type of written examination, e.g., open book, equations sheets, etc., is at the discretion of the Examination Committee.
2. The examinee will be notified of the outcome of the examination in writing by the graduate director.
3. If a student fails the examination or any part of it, the question of reinstatement and make-up of the exam is at the discretion of the Examination Committee. A student who fails the examination may be allowed to repeat the examination at the most, one more time.
4. Ph.D. candidates, i.e., those who pass the qualifying examination, are required to register for credit in the one-credit research seminar (650:608,609) for two (2) semesters after the examination. They should subsequently register in it for no credit.

Oral Part

At the discretion of the Ph.D. Qualifying Examination Committee, an oral examination may be scheduled.

Guidelines for Ph.D. Qualifying Examination

The purpose of studying for the Ph.D. Qualifying Exams is to motivate the students, now as more mature individuals than when they started their graduate studies, to review and study their course material in an intensive environment with the intent that such a review will enable them to better understand the original material and to begin to see the larger connections between subjects and disciplines.

The purpose for taking the Ph.D. Qualifying Exams is to enable the faculty to assess whether each student has mastered the material necessary to pursue more advanced study and research. This includes mastery of fundamental concepts, physical understanding needed for modeling phenomena and processes relevant to the subjects that comprise the discipline, working knowledge of the mathematical tools needed for quantification and for solving the relevant equations, and the ability to extract practical conclusions from the results.

Even though students are required (or strongly recommended) to take a certain number of courses before the qualifying exam, there really is not a one-to-one correlation between recommended courses and contents of the exam. In each exam students are required to know certain basic topics, as described below. Many Ph.D. students join our program after they receive their M.S. degrees from other institutions and the course material covered in courses they took before coming to Rutgers may be different than what we cover here. Students are **required to know the basic undergraduate material** in the subjects they are examined.

Click here for a more detailed description of the rules and procedures for the qualifying exam.
Following is a description of the subject material for the qualifying examination:

Design and Control

The exam in Design and Control tests the basic knowledge of students in the areas of study listed below:

Kinematics: Students should have a basic understanding of mechanism analysis and design. They should be familiar with basic approaches to mechanism kinematic analysis as well as synthesis. Students should be familiar with measures of merit such as mechanical advantage, transmission angle, and structural error. In analysis, students should know about two and three-dimensional kinematics, including Denavit-Hartenberg parameters and screw algebra. In synthesis, students should know analytical and numerical precision point approaches as well as numerical optimization-based methods.

Dynamics (including basic vibration): The student should be able to apply the basic concepts of dynamics to the modeling and analysis of particles and rigid bodies. The ability to model and analyze the following are expected: (1) Kinematics - Particles, 3D rotation of rigid bodies, interconnected bodies, and rolling; (2) Kinetics - Derivation of equations of motion using Newtonian and Lagrangian approaches; (3) Qualitative Analysis - Energy and momentum methods, as well as other motion integrals; (4) Response - Eigenvalue analysis of single and multi-degree of freedom linear vibrating systems, as well as continuous systems.

Design: Students should have developed a basic ability of converting real-life design problems into design models, applying various analytical, computational and optimization methods, generating realistic solutions and interpreting the results. A basic understanding of function based performance criteria and constraints, of strength of materials, of the role played by material properties, and of failure and safety factors is necessary. Basic understanding of underlying concepts of different design representations, manufacturing methods, finite element methods and optimization algorithms is needed.

Mechanics of Materials: Students should know plane stress and plane strain formulations, principal stresses in two and three dimensions, beams, membranes, plates and shells, as well as basic constitutive equations.

Solid Mechanics

The student should have a basic understanding of the foundations of solid mechanics, analytical dynamics and applied mathematics. The analytical dynamics and mechanics of materials requirements are described in the previous subsection. The other two main areas of study in solid mechanics are Continuum Mechanics and Elasticity, as described below:

Continuum Mechanics: Elementary tensor analysis, Cartesian components, traction and Cauchy stress, finite and infinitesimal strain, kinematics and material rates of change, balance laws, material symmetry. Elasticity, plasticity, fracture and fluid mechanics as special branches of continuum mechanics.

Elasticity: Finite strain, elastic energy, linear elastic constitutive equations, material symmetry. Elementary solutions for extension and bending. Torsion of cylindrical rods including noncircular cross-sections, Prandtl's stress function, complex variable methods for torsion. Plane stress and strain, Airy's stress function, 2D problems in rectangular and cylindrical coordinates. Betti's reciprocal theorem, the principle of virtual work, minimum energy theorems. 3D solutions in cylindrical and spherical coordinates, point load solutions: Kelvin's and Boussinesq's problems.

Mechanics of Materials: Students should know plane stress and plane strain formulations, principal stresses in two and three dimensions, beams, membranes, plates and shells, as well as basic constitutive equations.

Dynamics (including basic vibration): The student should be able to apply the basic concepts of dynamics to the modeling and analysis of particles and rigid bodies. The ability to model and analyze the following are expected: (1) Kinematics - Particles, 3D rotation of rigid bodies, interconnected bodies, and rolling; (2) Kinetics - Derivation of equations of motion using Newtonian and Lagrangian approaches; (3) Qualitative Analysis - Energy and momentum methods, as well as other motion integrals; (4) Response - Eigenvalue analysis of single and multi-degree of freedom linear vibrating systems, as well as continuous systems.

Suggested References:

Y.C. Fung, Foundations of Solid Mechanics, Prentice Hall, 1965.
Y.C. Fung, A First Course in Continuum Mechanics, Prentice Hall, 1977.
L.E. Malvern, Introduction to the Mechanics of a Continuous Medium, Prentice Hall, 1969.
I.S. Sokolnikoff, Mathematical Theory of Elasticity, Krieger, 1983.
S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw-Hill, 1969.

Fluid Mechanics

The specific objectives are to test the student's understanding of fundamental principles in fluid mechanics, as well as his/her ability to synthesize the various topics into a single global perspective on the field. In this context, understanding implies being able to derive the important governing equations, and to apply well-developed physical insight coupled with strong theoretical skills to solve complex problems.

The exam is typically given at two distinct levels. The first exam (specialist) is targeted at students intending to specialize in some aspect of fluid mechanics. The second exam (cognate) is for students whose chosen field of expertise requires some degree of understanding of fluid mechanics, but is not the central focus, such as for students specializing in the thermal sciences.

Both exams test for the student's mastery of introductory fluid mechanics concepts at the undergraduate and graduate levels. Students are asked to demonstrate their ability to derive key governing equations (mass, momentum, energy and vorticity) in both differential and integral form (where appropriate) as well as to provide exact solutions of these equations for different conditions.

The level of the specialist exam transcends the cognate exam by testing the student's detailed knowledge in specific topical areas along with his/her ability to synthesize material from different topical areas. Questions for the specialist exam, in addition to those described in the previous paragraph, are drawn from the full spectrum of fluid mechanics courses offered by the Department. In the context of testing synthesis skills and probing the student's depth of knowledge, open-ended questions combining a number of the above topics are also appropriate. The exam is structured so that the student need only demonstrate proficiency in two to three specialized topics in addition to the base knowledge covered in the two semester graduate fluid mechanics series.

Thermal Processes

This exam, like the fluid mechanics exam, is offered at two levels, one for students specializing in thermal sciences and the other for students is for students whose chosen field of expertise requires some degree of understanding of thermal sciences, but is not the central focus, such as for students specializing in fluid mechanics. The areas of study are:

Thermodynamics: Laws of classical thermodynamics, fundamental relations, energy analysis of processes, prediction of material properties, stability and phase transitions, reactive processes, equilibrium. Introduction to statistical thermodynamics, micro-and macro-canonical approach, the Boltzman distribution, modeling ideal gases, generation of property data.

Heat Transfer: Basic processes involving heat transfer by conduction, convection and radiation. Formulation and modeling different single and multi-dimensional processes with temperature gradients in solid and fluid media. Conjugate heat transfer with stationary and also moving boundaries due to phase change. Effect of radiation interaction at the boundaries. Effects of material properties, and scaling.

Exact, approximate, and finite difference methods of solution for basic steady and unsteady conduction heat transfer problems. Exact and approximate solutions for basic internal and external fluid flow problems with laminar and turbulent flow. Effect of body forces in free and combined free and forced convection. Boundaries with injection or blowing, and phase change. Effect of temperature dependent properties. Compressible flow. Analysis using empirical correlations.
Radiation: Radiation analysis in enclosures without a participating medium. Directional and spectral emission and absorption characteristics of surfaces.

C. Dissertation

Dissertation Committee

For each student that passes the Ph.D. Qualifying Exams, the Graduate Director in consultation with the student's research advisor forms a committee of three faculty, one of whom is the student's research advisor, from the ranks of the MAE Department, which will eventually comprise the student's Dissertation Committee. The external examiner may, but need not be, appointed at this time. Within a year of the forming of this committee, a dissertation proposal will be presented to the committee, in a public meeting, for review. This is important: The student must defend his/her proposal within a year of passing the Qualifying Exam. The prevailing opinion on this proposal will be that of the student's advisor. The other two faculty members will have an advisory role where suggestions are provided. These two faculty members will also follow the work of the student to the extent that is reasonable and warranted. The abstract and text of the proposal will be submitted to the Graduate Program Director and placed in the student's file.

There are a number of reasons for following this procedure. The student and faculty advisor benefit by having more formal access to their colleagues. The two committee faculty members can follow the research and can make constructive suggestions long before the actual defense. This makes the committee input more meaningful and removes some of the negative aspects of providing the committee too short a time to review a substantial amount of research at the very end of the process when there is little likelihood of change. The committee would be seriously encouraged to bring in the external examiner at six to twelve months prior to the estimated completion of the student's research for similar reasons. This process in no way reduces the authority of the faculty research advisor as the lead in the research effort, its methods and goals, and in determining issues such as publications, presentations, and milestones.

Dissertation Proposal Examination

Upon successful completion of the written qualifying exam the qualifying exam committee and the Graduate Program Director will sign the candidacy form and the student will formally be admitted to candidacy for the degree of Doctor of Philosophy. At this time the student's *doctoral committee* will be formed. The committee will be comprised of the student's dissertation research advisor plus two members of the graduate faculty in Mechanical and Aerospace Engineering and an external member (a faculty member who is not part of the M&AE graduate program). Within one year of successful completion of the qualifying exam, the student will write and present to his/her doctoral committee a*dissertation proposal*. The student must then pass an oral exam administered by his/her committee based on any completed research and the proposed research. The outcome of the exam will then be reported to the Graduate Program Director.

Dissertation and Defense

The culmination of the student's doctoral work is the writing of the Ph.D. dissertation. When the dissertation advisor approves the written work, he/she will notify the Graduate Program Director who will, in turn, send copies to the student's doctoral committee for reading, comments and criticism. After each member of the committee reads and approves the dissertation, the Graduate Program Director will schedule a final oral dissertation defense in a **public** forum. Upon successful completion of the defense, and acceptance of the final form of the dissertation by the committee, the committee will sign the dissertation indicating their approval. The candidate will then have the *candidacy form* signed by the committee and the Graduate Program Director. The last step is to submit the signed form and dissertation to the Graduate School.

Public Defense of Dissertation and Final Examination

The following procedure is followed for the public defense of the dissertation.

- The candidate obtains from the Graduate School the previously completed candidacy form and brings it to the defense.
- The examination is presided over by the candidate's dissertation advisor and consists of an open portion and a closed portion. The open portion consists of an approximately 45 minute presentation by the candidate on his/her dissertation. This is followed by approximately 30-45 minutes of questions from the committee and from the public. The closed portion is attended by the examining committee only, who may elect to question the student further on his/her dissertation, or in areas related to it.
- The candidate is excused and the student's Dissertation Committee, and the Graduate Director, if so interested, meets to reflect on the examination and to complete the candidacy form.
- The candidate returns the candidacy form to the graduate secretary. The form will be kept in the student's folder until recommended thesis revisions are made. A bound copy of the revised thesis must be presented to the Graduate Director along with the candidacy form. The Graduate Director's name will be the final signature on the form. This bound copy is used as a reference within and outside the department.

NOTE: The Graduate School requires the following:

You must submit one copy (not bound) of the dissertation on 100% rag or cotton content paper. The title page must have the original signatures (in black ink); five (5) extra copies of the title page, and three (3) extra copies of the abstract are also required and finally the candidacy form certified by the Graduate Director.

NOTE: The MAE Department gets a bound copy of the dissertation (see dissertations in Room B-234) and one (1) copy of the abstract. If you can, please also submit to us a pdf copy of the dissertation). A copy of the signed candidacy form will be kept on file within the MAE Department.

Diploma Application Forms may be obtained from the graduate secretary.

The deadline for submission of this form is the beginning of the following months:

October--for an October dated degree
January--for a January dated degree
April--for a May dated degree

Please be sure that you are consistent in the use of your name on the diploma application and title page of your dissertation. The way it appears on the diploma application should be the same as your name appears on the title page of your dissertation.

Combined B.S.- M.S./ B.S.-M.Eng. Program in Mechanical and Aerospace Engineering

The Combined B.S.-M.S./ B.S.-M.Eng. program enables top Rutgers undergraduate students to be accepted into our graduate program in an expedited way. In addition, it gives those students the possibility to receive an M.Eng. or an M.S. degree in a shortened time frame.

Eligibility

Rutgers MAE undergraduates who have a GPA of 3.2 or higher and have completed (or are completing) their sixth semester are eligible to apply to the B.S.-M.S./B.S.-M.Eng. program. Students usually apply during their sixth semester or before their seventh semester.

Eligibility requirements are identical to those for the James J. Slade Scholars Program of the SOE.

Student must have completed 96 credits of coursework at the end of their sixth semester of undergraduate study.

The GRE requirement is waived for students in the B.S.-M.S./B.S.-M.Eng. program. Students should fill out the application form and submit it to the MAE Graduate Office with two letters of recommendation and a personal statement.

Students must have at the time of their application a 3.2 GPA and they must maintain a 3.2 GPA throughout their senior year.

Study Programs

The B.S.-M.S./B.S.-M.Eng. program provides students with the opportunity to get a Master's degree within a shortened time frame.

This becomes possible if you enroll in the SOE J.J. Slade Scholars Program or take one or more graduate-level courses in the senior year in addition to undergraduate degree requirements. The plan of study in the Graduate School is as follows:

M.Eng.: 30 course credits plus project, report, and oral presentation.
M.S.: 24 course credits plus six research credits plus M.S. thesis and defense.

The following is a recommended study sequence:

Summer following third year (optional): Apply for a summer internship or fellowship program and begin research/project work.

Senior year: Enroll in Slade Scholars Program. Take six credits of 650:491 and 650:492, which count as course credits towards M.S./M.Eng. degree. Research can become the thesis topic for the M.S. degree. Students can take graduate courses, if prepared.

Fifth year: Three courses and three credit hours of research each semester. You can take fewer courses each semester, but this would lengthen the duration of the Master's studies.

Summer (and perhaps fall) following fifth year: Write M.S. thesis and defend/ write M.Eng. project report and present

Note: Students can change advisors at the end of their fourth year. The Slade Scholar topic does not necessarily have to be the M.S. thesis topic or M.Eng. project topic.

Application Procedure

1. Fill out the B.S.-M.S./ B.S.-M.Eng. Degree Application Form (click here for form),
2. Attach a copy of your transcript (you can download from web)
3. Brief personal statement
4. Two letters of recommendation

Once you are admitted and you maintain the requirements discussed earlier, then during the Spring semester of your studies you will receive official notice from the MAE Graduate Program that you have been admitted. You do **not** need to submit a formal application to the Rutgers Office of Graduate and Professional Admissions. Even though you do not submit an application to OGPA, you will receive an official admissions letter from OGPA a few weeks after you are notified by the MAE Dept. That's it!

Certificate Programs

The Graduate Program in Mechanical and Aerospace Engineering participates in two certificate programs offered by Rutgers University.

Certificate in Engineering Geophysics

Engineering geophysics is a new field which applies geophysics to engineering with reference to a broad spectrum of societal and industrial environmental problems. The certificate program offers students the opportunity to broaden and strengthen their backgrounds with emphasis on environmental applications by taking selected courses from graduate programs in engineering, geological sciences, and oceanography, in conjunction with existing M.S. and Ph.D. Programs.

For MAE students, the program can provide training in geophysical methods and a geological and marine context for engineering applications. This multidisciplinary training can provide a competitive edge in research and in the job market.

MAE graduate students who participate in this certificate program must, as part of the courses that count toward their degree, take three courses in the participating graduate programs outside MAE, including at least one course in geophysics. These courses are selected by the student and the graduate director, in consultation with the director of the certificate program, Prof. Peter Rona.

More information is available from the Engineering Geophysics web site.

Operations Research Option in Design Optimization

Operations Research (OR) is an interdisciplinary science, based on the use of mathematics, statistics, computer science, and economics for the analysis and solution of problems in business, industry, government, etc. Mechanical and aerospace engineers frequently rely on OR to analyze complex real-world problems, their formulation as mathematical models, development of mathematical and statistical methodologies for the solution of such models, as well as development of computer algorithms and software for the determination of optimal solutions.

The Operations Research Option is a program through RUTCOR (Rutgers Center for Operations Research) aimed at introducing MAE graduate students (M.S. or Ph.D.) to the basic methodologies and applications of operations research, and preparing them for work on the practical and theoretical aspects of OR.
Requirements of the Option in OR are: 1) Completion

of all MAE requirements,

2) Two required courses:

- 650:614 - Optimal Design in Mechanical Engineering
- 198:521 - Linear Programming

3) Plus, two courses from the following list:

- 711:513 - Discrete Optimization
- 198:524 - Nonlinear Programming Algorithms
- 711:525 - Stochastic Models of OR
- 711:555 - Stochastic Programming

These courses can be counted towards the program of study of the student leading to the M.S. or Ph.D. degrees. It is anticipated, but not required, that the M.S. Thesis Committee or the Ph.D. Dissertation Committee have one member from RUTCOR. A student graduating with an M.S. or Ph.D. in MAE and an Option in OR will receive a Certificate signifying that he or she has completed a prescribed course of study in Operations Research as Applied to Mechanical and Aerospace Engineering.

Note: The Option in OR is different than receiving a minor in Operations Research. For more information on a minor in Operations Research click here.

M.Eng. Checklist

MAE M.Eng. Graduation Checklist Requirements

Total of 30 course credits
- B average
- max 1 C grades
- max 2 undergraduate level (only 400 level. Requires prior approval by GPD)
- max one independent study
- up to 12 course credits with grades of B or better can be transferred from another institution

Math course 642:527
21 MAE courses credits
Enrolled in seminar every semester (minimum 3 semesters), (1-course credit ea), barring exceptions

Procedure after Completing All Requirements

1. Sign up for M.Eng. Exam by due date after date is announced.
2. Present project at M.Eng. Exam.
3. Bring essay/report to M.Eng. exam and submit to committee (cover sheet form on MAE website).
4. Bring candidacy form (completely filled out) to exam.
5. Upon passing exam, have committee sign candidacy form.
6. Bring signed candidacy form to Graduate Program Director for approval.
7. Take approved candidacy form to GSNB.
8. Fill out diploma application and send to the registrar.

M.S. Checklist

MAE MS Graduation Checklist Requirements

Total of 24 course credits
- B average
- max 1 C grades
- max 2 undergraduate level (only 400 level. Requires prior approval by GPD)
- max one independent study
- up to 12 course credits with grades of B or better can be transferred from another institution

Math course 642:527
15 MAE course credits
Six research credits with grade of S
Enrolled in seminar every semester (minimum 3 semesters), (1-course credit ea), barring exceptions

Procedure after Completing All Requirements

1. With consent of advisor, submit three copies of thesis to Graduate Program Director.
2. Graduate Program Director appoints the thesis committee and sends thesis for review.
3. After committee approves, thesis exam is scheduled and public notices posted at least four days before exam.
4. Bring candidacy form (completely filled out) to exam.
5. Upon passing exam, have committee sign candidacy form, complete corrections on thesis, after which you have committee sign the thesis cover sheet.
6. Bring signed candidacy form and a copy of thesis to Graduate Program Director for approval.
7. Take approved candidacy form and a copy of the thesis to GSNB.
8. Fill out diploma application and send to the registrar.

Ph.D. Graduation Checklist

MAE PhD Graduation Checklist Requirements

1. Total of 48 course credits
   B average
   max 2 C grades
   max 2 undergraduate level (only 400 level. Requires permission of GPD)
   max two independent study (one at M.S. level one at Ph.D. level)
   up to 24 course credits with grades of B or better can be transferred from another institution
2. Math courses 642:527, 642:528
3. Minimum 30 MAE course credits.
4. One graduate level course from each area of specialization within MAE.
5. 24 research credits with grade of S.
6. Enrolled in seminar every semester (minimum 6 semesters), (1-course credit ea), barring exceptions.
7. Pass qualifying exam.
8. Dissertation proposal submitted (within one year after passing qualifying exam) and passed.
9. Outside Committee Member selected.
   If outside Rutgers, GSNB needs to approve.

Procedure After All Requirements are Satisfied

1. With consent of Advisor submit dissertation to Graduate Program Director (GPD).
2. GPD sends dissertation for review.
3. Schedule defense after approval by committee members.
4. Public notices of the defense must be posted at least five days before defense.
5. Go to GSNB, pick up candidacy form, completely fill it out and bring to defense with you.
6. Upon passing defense, have committee sign candidacy form, complete corrections on dissertation, and have committee sign the dissertation cover sheet.
7. Bring signed candidacy form and a copy of dissertation to GPD for approval.
8. Take approved candidacy form and a copy of the dissertation to GSNB.
9. Fill out diploma application and send to the registrar.

Graduate Course and Registration Information

The graduate program in Mechanical and Aerospace Engineering (MAE) offers a wide variety of graduate level courses. We also encourage our students to take courses from other graduate programs. Please click on the links on the menu on the left to obtain more information about our graduate course offerings.

Below please find registration information and policies regarding maximum credits, transfer of credit, and courses from other programs. Please read carefully.

Registration Procedures

There are several times during the year when you will register for courses offered by the Graduate School. In addition to your initial registration, these dates are as follows:

Registration Deadlines:

Registration for spring term	November
Registration for fall term	March
Registration for summer research	March - July

Continuing students who fail to pre-register during these specified periods can register later, but a late fee of $50 (subject to change) is imposed. If you have a valid reason for not preregistering, see the graduate director to find out if the late fee can be waived.

To look at courses that are offered, you can go the Administrative Computing Services course search engine. The Graduate Director will provide more information regarding courses offered for each semester. Please look at the web site of the New Brunswick/Piscataway Registrar for more information and deadlines.

Numbers required for registration: School 16, Major 650. Class codes are 10 - M.S. students, 40 for Ph.D. students (pre-qualifying exam), 50 for Ph.D. candidates (after passing the qualifying examination).

Taking Courses from Other Graduate Programs/Taking Undergraduate Courses

The MAE graduate program has the following policy for registering in courses outside our graduate programs or undergraduate level courses and receiving graduate credit from MAE, subject to the approval of the Graduate Program Director:

Special permission from the graduate program director is **NOT** needed to take graduate level courses in the following programs: All engineering, mathematics, physics, chemistry.

Special permission from the graduate program director **IS** needed to take graduate courses in all other programs for graduate credit in MAE.

Special permission from the graduate program director **IS** needed to take undergraduate level courses for graduate credit in all programs, including from MAE Dept. Note that we only approve graduate credit for 4xx level courses. Also, an MAE graduate student can take a maximum of two undergraduate courses for graduate credit.

To obtain special permission for one of the courses in the above categories, the student must contact the graduate program director in writing. Once the permission is granted, a copy of the permission will be placed in the student's file. If the permission is for a 4xx level course, the student has to use the "G" prefix when registering. An MAE graduate student is not allowed to use the "G" prefix for a 4xx level course for which special permission is not granted.

If you take a graduate level course that requires special permission from MAE without obtaining the special permission that course will NOT count towards your degree. Your transcript will indicate that you have completed that course, and will show graduate credit but MAE will not count the course towards your degree.

Course Credit Information

A graduate student may take a maximum of 16 credits in a given semester.

Any student wishing to take more than 16 credits in a given semester must get the approval of the Program Graduate Director and the Graduate School, 25 Bishop Place, College Ave.
Campus. GAs and TAs are required to register for 650:866 or 650:877 (6 credits) indicating the 'E' credit prefix. Students holding appointments will receive the form RT100, Tuition Remission Application--Graduate from the MAE Department Office B-235. Return the RT-100 card with your term bill to the cashier in Administrative Services Building, Busch Campus.

Teaching Assistantship and Graduate Assistantship credits *are included* in this count of 16 credits, so a student with a full Teaching Assistantship or Graduate Assistantship (6 'E' credits) is entitled to 10 credits of course work for a total of 16 credits. Excess credits will not be approved when research credits are involved. Registration for excess credits may, however, be considered when English as a Second Language course work is involved.

Students beginning their first semester must complete a registration form provided by the registrar.

Changes in Registration

Course registration may be changed within the first two weeks of a semester. Please look at the web site of the New Brunswick/Piscataway Registrar for more information and deadlines.

We ask that you consult your adviser or the Graduate Director regarding changes even though the registrar will accept changes without formal approval. A simple error can change your status in the Graduate School, a change that may affect your program. For example, a full-time student will automatically lose his/her full-time status if the number of credits drops *below 9 credits*. After the initial two-week period, the only changes allowed are course drops. The required signatures depend on the number of weeks elapsed since the beginning of the term. Refer to the Graduate School Academic Calendar for specific dates.

If you plan to discontinue your studies for one or two terms, you must enroll in 650:800Matriculation Continued. Registration in this "no-credit" course will retain your active status. However, enrollment in this course beyond two terms may result in the need to apply for readmission. M.S. students or Ph.D. students who have completed less than 30 credits, or who have been admitted to Candidacy for the Ph.D. must file a Restoration of Active Status form.

Transfer of Credit from Another University

A student in the M.S. program can transfer up to 12 course credits from another institution or from another academic unit at Rutgers (such as the MAE undergraduate program). The transferred courses must be at the graduate level and with grades of B or better. The transfer process requires approval of the Graduate Director of MAE, as well as approval of the Graduate School. You must fill out the transfer of credit form (available in B226) in triplicate.

A student in the Ph.D. program can transfer up to 24 course credits from another institution. Same rules apply as in the M.S. Program.

Note: In order to be eligible for transfer credits, a student must first complete 12 credits at Rutgers with grades of B or better.

Independent Study

A student in the M.S. program may register for only one Independent Study (650:601, 602) course. A doctoral student may register for two Independent Study courses if they have not taken an independent study at the M.S. level. A doctoral student who has taken an independent study in their M.S. can only take one additional independent study at the doctoral level.

Registration Information for New Students

You should follow the procedure below when registering as a new graduate student:

- Make sure you attend the orientation sessions offered by the Graduate School and by the International Office. This is especially important for foreign students, as the number of requirements that you need to be aware of has increased in recent years.

- International Students: Before you arrive at Rutgers, please look at some information provided by the Center for International Students and Faculty.

- When you arrive at Rutgers, you must first visit the Center for International Students and Faculty and the MAE Graduate Program Office (B226 in the Engineering Building). At the International office you will let them know that you have arrived, attend orientation sessions and learn about how to register yourself with U.S. immigration authorities.

- You need to come by the MAE Graduate office to let us know that you have arrived, to introduce yourself, to meet the Graduate Program Director (Prof. Baruh) and Graduate Program Secretary (Mrs. Jenkins), to have your picture taken, and to make an appointment with Prof. Baruh for your registration. You can drop by, or you can send us an email to make an appointment.

- The Graduate Program Director will give you an overview of the MAE Department, our graduate course offerings and other general information. Also, you will discuss courses you want to take and the Graduate Program Director will sign your registration form. If you have a GA appointment you should meet with your professor after (or before) you meet with the Graduate Program Director.

- During your meeting with the Graduate Program Director, you will also fill out the registration form. Your first registration at Rutgers has to be done in person. After that, you can add/drop classes or register for future semesters by yourself, and you won't need the approval of the Graduate Program Director.

- If you have financial support in the form of a TA, GA or Fellow, you next have to go to the MAE Dept. office (in Room B235) and you will be added to the payroll (so you can receive a salary) and also given form RT-100 (tuition remission form). This is the form you will use at the Cashier's Office to receive your tuition remission.

- Once you have your registration form signed, you then go to the Registrar, which is located in the Room 200F of the Administrative Services Building (ASB). If you draw a line from the Engineering building to the Busch Student Center, ASB can be found by extending that line. There, you submit the registration form and officially register.

- Once your registration is accepted, you will be given a term bill which shows the tuition you owe. Depending on the day you register, you will have up to two weeks to pay the term bill. The term bill needs to be paid at the Cashier's Office.

- If you have tuition remission from Rutgers and have the RT-100 form with you, submit the RT-100 form, together with your term bill, to the Cashier.

- Once your term bill is paid, you are officially a Rutgers student. Your next step is to go to the Busch Student Center and have your identification card prepared. You should do this one day after your term bill is paid. Your photograph will be taken and you will be issued the RU identification card. The student identification number that is given to you is different from your Social Security Number.

- Once your registration is complete, you will also receive a Rutgers mailbox number (mailbox located at Busch Student Center) as well as an email account from the university. You will also have a mailbox at the MAE Graduate Office. Your mailbox at the MAE Graduate Office is for official Rutgers business only, personal use is not permitted.

Your School Code is 16, and the MAE Department code is 650.

To look at courses that are offered, you can go the Administrative Computing Services course search engine or to the MAE Course Listings.

A graduate student may take a maximum of 16 credits in a given semester. Any student wishing to take more than 16 credits in a given semester must get the approval of the Program Graduate Director and at the Graduate School, 25 Bishop Place, College Ave. Campus. GAs and TAs are required to register for 650:866 or 650:877 (6 credits) indicating the 'E' credit prefix.

Teaching Assistantship and Graduate Assistantship credits *are included* in this count of 16 credits, so a student with a full Teaching Assistantship or Graduate Assistantship (6 'E' credits) is entitled to 10 credits of course and/or research for a total of 16 credits. Excess credits will not be approved when research credits are involved. Registration for excess credits may, however, be considered when English as a Second Language course work is involved or other special circumstances.

The following sample registration form is given as a guide.

Name: Typical Graduate Fellow **Rutgers I.D. No.**

School: 16 Class (10), (40) or (50) **Billing No.** **Term**: Fall/Spring, 20--

Course Title	School No.	Subject No.	Course No.	Section No.	Credits	Index No.	By Arr.	Credit Hr. Pref.
Fluid Mech. I	16	650	530	01	3	xxxxxx		
Expert Systems	16	198	587	01	3	xxxxxx		
Vibrations	16	650	661	01	3	xxxxxx		
MAE Research	16	650	701	B1	--	xxxxxx	6	
MAE Seminar	16	650	608/9	01	1	xxxxxx		N
Fellowship	16	650	811	01	0	xxxxxx	0	
Grad. Assist.	16	650	855	01	--	xxxxxx	6	E
Teach. Assist.	16	650	877	01	--	xxxxxx	6	E

Advisor's Signature _____ Total Credits: 16

Course registration may be changed within the first two weeks of a semester. Please look at the web site of the New Brunswick/Piscataway Registrar for more information and deadlines.

Course Offerings

500 Level Courses (No Grad PreReqs)	600 Level Courses
Interdisc. (00-09) 650:500 Experimental Methods 650:504/5 Mathematical Methods in Engineering 1,2	650:601/2 Independent Study 650:604 Advanced Engineering Analysis 650:606 Advanced Mechanical Engineering Topics 650:608/9 Seminar in MAE 650:699 Nonthesis Study 650:701/2 Research in MAE
Design and Control (10-29) 650:510 Computer Aided Design 650:512 Robotics and Mechatronics 650:514 Design of Mechanisms 650:518 Biomechanical Systems 650:522 Analytical Dynamics 650:524 Optimal Design in Mechanical Engineering	***(Recommended for Ph.D.: 550, 514, 522, 524)*** 650:618 Special Applications in Control 650:622 Advanced Optimization 650:626 Advanced Design and Fabrication
Fluid Mechanics (30-49) 650:530 * Fluid Mechanics I 650:532 Experimental Methods in Fluid Mechanics 650:534 Computational Fluid Mechanics	***(Recommended for Ph.D.: 530, 570, 574, 630)*** 650:630 Fluid Mechanics II 650:631 Fluid Mechanics III 650:634 Mechanics of Compressible Fluids 650:636 Turbulence 650:638 Hydrodynamic Stability 650:640 Acoustics 650:642 Suspensions
Solid Mechanics, Materials and Structures (50-69) 650:550 * Mechanics of Materials 650:554 * Mechanics of Continua (SM I) 650:556 Theory of Elasticity (SM II)	***(Recommended for Ph.D.: 522, 550, 554, 556)*** 650:651 Mechanics of Inelastic Behavior (SM III) 650:652 Composites, Fracture, and Thermo. (SM IV) 650:653 Structural Mechanics (SM V) 650:654 Dynamics of Solids and Structures (SM VI) 650:660 Finite Element Methods in Solid Mechanics 650:661 Advanced Mechanical and Random Vibration 650:662 Advanced Stress Waves in Solids 650:663 Advanced Plasticity 650:664 Advanced Fracture Mechanics 650:665 Advanced Composite Materials 650:666 Advanced Micromechanics

	650:667 Advanced Stability of Elastic Systems 650:668 Advanced Viscoelasticity 650:669 Advanced Thermoelasticity
Thermal Processes (70-89) 650:570 * Conduction Heat Transfer 650:574 * Thermodynamic Theory 650:578 Convection Heat Transfer 650:582 Computational Methods in Heat Transfer	***(Recommended for Ph.D.: 530, 570, 574, 578)*** 650:670 Combustion 650:674 Radiation Heat Transfer 650:678 Boiling and Condensation Heat Transfer 650:682 Thermal Transport in Materials Processing

*** 3 Required for MS**
*** Math 642:527 Also required for MS Math 642:527/8 Also required for Ph.D.**

For a typical two year course offerings sequence click here. Click here for a description of all MAE graduate courses. See below for a list of courses offered this year.

Typical Two-Year Course Sequence

This list is intended to be a guide for students to make their plans of study for the next two years. Please note that while we try to stick to this schedule as much as possible, there will be some minor changes every semester. Click here for the Rutgers University Course Database.

Fall Annually		Spring Annually	
		650:514	Design of Mechanisms
650:524	Optimal Design in Mechanical Eng.	650:522	Analytical Dynamics
650:530	Fluid Mechanics I	650:556	Theory of Elasticity (SM II)
650:550	Mechanics of Materials	650:574	Advanced Thermodynamic Theory
650:554	Mechanics of Continua	650:578	Convection Heat Transfer
650:570	Conduction Heat Transfer	650:630	Fluid Mechanics II

This leaves us about three to four course slots each semester to offer other subjects. A possible list is given below. These courses will be offered on alternate years.

Fall Biannual		Spring Biannual	
650:518	Biomechanical Systems	650:534	Computational Fluid Mechanics
650:532	Experimental Methods in Fluid Mechanics	650:654	Dynamics of Solids and Structures (SM VI)
650:582	Computational Methods in Heat Transfer	650:660	Finite Elements
650:653	Structural Mechanics (SM V)	650:510	Computer Aided Design
650:512	Robotics and Mechatronics	650:652	Composites Fracture and Thermo SM - IV
650:631	Fluid Mechanics III	650:674	Radiation
650:651	Mechanics of Inelastic Behavior SM-III		
650:670	Combustion		

Assorted Information

Ph.D. Qualifying Examination (PQE) Rules and Procedures

The PQE is used to determine whether a graduate student should be allowed into candidacy, that is, continue with research that would lead to the Ph.D. degree. It is a measure of whether a graduate student can tackle problems posed to him/her, be it a simple problem, similar to what was covered in a certain course, or a more complex, sometimes conceptual, problem that would require the student to combine knowledge from a number of topics and show analytical thinking skills.

We offer the PQE once a year in May, during the week after final exams. The current format of the PQE offered by the MAE Dept. is entirely written.

Even though MAE graduate students are recommended (or encouraged) to take a certain number of courses before the PQE, there really is not a one-to-one correlation between recommended courses and contents of the exam. In each exam students are required to know certain basic topics. Many of our Ph.D. students join our program after they receive their M.S. degrees from other institutions and the course material covered in courses they took before coming to Rutgers may be different than what we cover here. Also, students are required to know the basic undergraduate material, in addition to graduate level subjects.

After students take the PQE, the Ph.D. Examination Committee (PhDEC) members grade the papers and meet as a group to decide the final outcome for each student. Grading of the PQE is different than the way a midterm or final is graded in a regular course. What the committee is looking for is whether the students taking the PQE have a basic understanding of the material and what approach the students use to tackle a problem, even in a problem that they may have not seen in a course. Whether a student passes or fails depends on a general assessment of how the student's overall performance. In certain cases the PhDEC may take into consideration the research performance of the student.

The PQE can have three outcomes:

a) Student passes the exam,
b) Student fails the exam, in which case the student is given a second and final chance to take the qualifying exam the next time it is offered,
c) Student does well in most of the exam and poorly in a small part. In this case, the Committee may decide to give the student an additional written or oral exam on the part the student did poorly. This exam must be taken before the first January 20 following the PQE. The exam is administered by the same PhDEC that administered the PQE. If the student does well in the additional exam, then the student is considered to have passed the PQE. If the student does poorly, the student is considered as having failed the PQE and must re-take the PQE in its entirety the next time it is offered.

Note: A student may discuss the outcome of the PQE with the Graduate Director only. The Graduate Director may give permission to a particular student to talk with the chair of the Ph.D.

Examination Committee. The student is not allowed to contact a member of the Committee or a faculty member who wrote or graded a part of the exam. The student has a right to see his/her graded exam.

Two frequently heard questions are:
1) How come I got an A when I took this course and did poorly on the part of the PQE related to the course?
2) My exam on this particular subject had a question that was not covered in the course that I took related to the subject.

Both these questions arise from misconceptions about the Ph.D. qualifying exam and we hope the comments above are helpful.

Timetable:

Early February: Graduate Director (GD) confers with Ph.D. Examination Committee and sets the dates and times of the qualifying exam. Gives students notice to request admission into the exam.

Mid February: GD examines requests for eligibility. For eligibility, the student must be enrolled in the Ph.D. program (Ph.D. candidate, or if student is Ph.D. track masters he/she should be near completing M.S. degree).

Late February: Students are notified whether their request to take the qualifier is approved. Previous year's qualifying exam is made available to students admitted to the PQE.

Mid May: Students take the PQE, the exams are graded and the students are notified of the outcome.

Mid January: Students who did poorly in part of the qualifying exam and were given the opportunity to take an additional exam must have taken the additional exam.

Dates & Deadlines

Time Limits for Degrees

Visit the Graduate School web site for deadlines for degrees and diploma applications.

Degree programs should be completed within the following periods of time after first registration in the Graduate School-New Brunswick:

	Normal Minimum (full-time study)	Normal Maximum
Master of Science	2 year	3 years
Doctor of Philosophy (after B.S.)	4 years	6 years
Doctor of Philosophy (after M.S.)	3 years	5 years

All students are urged to consider carefully the educational and economic benefits of completing their programs as expeditiously as possible. Soon after being admitted to graduate study each student should consult with a faculty advisor and work out a reasonable timetable. Part-time students should consult their program concerning their expected times of completion.

Please note that available levels of financial support have declined in recent years and that it is in your best interest to finish your studies promptly.

Thesis and Dissertation Preparation

A pamphlet entitled "Style Guide for Thesis and Dissertation Preparation" is available at the Office of the Graduate School. All these, dissertations, or essays submitted to the Graduate School-New Brunswick in partial fulfillment of the requirements for graduate degrees must conform to the instructions in this pamphlet, and candidates should familiarize themselves with these instructions before they proceed to their final drafts. A thesis may be rejected by the graduate school office if it does not adhere to the stylistic and technical requirements.

The Graduate School provides Dissertation and Thesis Workshops to help students prepare their manuscripts for submission in accordance with the requirements of The Graduate School-New Brunswick. The workshops give students the opportunity to ask specific questions about the format of their project.

Graduation

When entering their final term, students should follow the procedures listed below:

1. Ensure that all academic requirements are being completed. If a student is unable to do so by the deadline date, both forms listed below must be re-filed for a later-dated diploma. 2. Ensure that related fees and any outstanding debts to the university are paid.
3. Submit the completed candidacy application form by the announced deadline, normally in early January, May, or October.
4. Submit a diploma application form by the announced deadline, normally January 2, April 1, or October 1. The degree cannot be conferred as scheduled, and graduation will be delayed, if this form is filed after the deadline has passed. All forms are available from the Graduate School. It is the responsibility of the student to complete all requirements for graduation by the scheduled dates. Please consult the checklists for the M.S. and Ph.D. degrees at least a semester before graduation.

Conferral of degrees and diplomas occurs once a year at the annual spring commencement. However, students who file the applications and complete all other requirements for the degree by the announced October or January dates will get a diploma dated for the respective month, although they will not receive it until the following spring. Students may, therefore, request a temporary certificate of completion by submitting a written request to the university registrar (Administrative Services Building) accompanied by a self-addressed, stamped envelope. At the time of commencement, degrees may be conferred in absentia only if the prospective candidate has notified the university registrar that he or she cannot attend the commencement exercises.

The diploma will be withheld from any student who is under financial obligation to the university.

Lab Guidelines

The following notes on laboratory safety and security rules and procedures are included because most graduate students study or do research in one of the many laboratories in the department. Over the years the University has developed guidelines to be observed within the laboratories. These guidelines, in part, are given below. For the most part, the guidelines are common sense. The reasoning behind a specific one may not be immediately evident. However, often a rule arose because of a serious injury, a near accident or the theft of equipment. These rules are not and probably cannot be all inclusive, but they do establish an awareness and a guide to a course of action. It is essential that we remain alert and use good judgment in our laboratories.

General Laboratory Guidelines

- Laboratory facilities are for department related activities only. These include teaching, research, and sanctioned student societies.
- General hours of operation are from 8:30 am to 4:30 pm, Monday through Friday.
- Use of laboratory facilities outside of the general hours noted above is restricted to authorized University personnel (i.e., faculty, technicians, research students and staff, and teaching assistants).
- Other individual(s) seeking access to the laboratories outside of general hours must be accompanied at all times by a faculty or staff member who accepts full legal responsibility for said individual(s).
- Student use of laboratory equipment must be directly supervised by a technician or instructor (see also Machine Shop Rules).
- Technicians are available for tool sign out, consultation, training, and other general needs between the hours of 9:00-11:00 am and 1:00-3:00 pm, Monday through Friday.
- More involved requests for technician time will be handled by appointment. 'Technician Support Request' forms will be available outside D-129 and D-117A.
- All activities must conform to university regulations on health and safety.

General Laboratory Safety

1. In case of any emergency dial the University Police, extension 6/911. Use any available campus phone. There is one on the wall outside Room D-134 in the main bay area of D-

123. Also, report the incident to the Department Office, Room B-235, extension 5-2248.

2. Emergency exits, alarms, fire extinguishers, safety showers and also blankets for wrapping are strategically located in or near our laboratories. Some of these are marked on the attached floor plan. Their location should be noted. In particular, there are two emergency exits at the rear of the main bay area by the roll-up doors in D123. Emergency doors are also located in D119 and in D124. The doors located in D-119 and D-124 are connected to an alarm and should only be used in the event of emergency.
3. Fire regulations require that an aisle, at least 30 inches wide, be clear of any obstructions near all exits, safety equipment and power shutoff controls.
4. Smoking is never permitted in this building.
5. Know the potential hazards of the material, facilities and equipment with which you will be working.
6. Small quantities, 5 gallons or less in approved containers, of inflammable liquids may be stored in the laboratories. Glass containers should not be used for that purpose. Fire regulations *prohibit* storing them in closed cabinets or in refrigerators. Larger amounts are to be stored in the outside hazardous storage shed on the south side of D wing. Both Bill Vasiliou and the Department office have a key to the storage shed.
7. State regulations require a label on each container of any substance, liquid or otherwise. The label should indicate the chemical generic name and, if hazardous, the chemical formula. Also, if the substance is hazardous, the nature of the hazard, i.e., toxic, inflammable, etc., must be indicated. The laboratory technician has state-issued regulation labels which are to be added to each container of hazardous material. These labels identify the substance to be hazardous.
8. Your *research* director is required to maintain an inventory of such hazardous substances indicated above and needs your cooperation in keeping informed of inventory changes. The Laboratory Director is required to maintain an inventory of such hazardous substances that are not acquired for research.
9. The university arranges for periodic waste disposal of unwanted hazardous substances. Arrangements for *all* such disposals should be made through the Laboratory Director. Waste should not be accumulated. The State requires that containers of waste material be labeled with special waste disposal labels. These labels are obtained from the laboratory mechanic. The Laboratory Director cannot accept your chemicals for disposal without proper labeling.
10. Alterations to any of the laboratory utilities (water, gas, air, electric, sewer, etc.), require specific approval from the Laboratory Director. Mr. Vasiliou will supervise or do all such work *after* permission is given if the university physical plant personnel do not do the work.
11. Do not leave loose material in the laboratory trenches and do not construct any obstructions to water flow there. There are 110/220/440 volt electric service lines mounted on the trench walls.

Machine Shop Rules

Access:

- General hours of operation are 8:30 am - 12:00 noon and 1:00 - 4:30 pm, Monday through Friday.
- Use of power equipment during general hours is restricted to individuals who have been certified by one of the technicians or who are directly supervised by a technician.
- Use of power equipment after hours is restricted to authorized University personnel (see General Laboratory Guidelines) who have been previously certified by the technicians. Access to the machine shop will be permitted on a case by case basis by the technicians.
- Technicians are available for consultation, tool sign out, training, and certification between the hours of 9:00-11:00 am and 1:00-3:00 pm, Monday through Friday (see General Laboratory Guidelines).

Safety:

- Safety glasses must be worn at all times.
- Long (shoulder length or longer) hair, loose clothing, and jewelry must be tied back or, if possible, removed.
- Follow all instructions for each machine.
- Securely clamp all pieces in at least two places (particularly when drilling large diameter holes).
- A designated 'buddy' must be on the premises at all times while power equipment is in use.
- Clean up is a matter of both courtesy and safety. This includes removal of waste material from both the machine and the floor around the machine.
- Violation of any safety regulation will result in immediate suspension of shop privileges.

Departmental Office

The Mechanical and Aerospace Engineering Department Office is located in Room B235 of the College of Engineering. This office handles payroll, keys, etc. Office hours are 8:30 a.m. - 4:30 p.m. The office is closed for lunch from 12:00 - 1:00 p.m.

Mailboxes

MAE graduate students have two mailboxes at Rutgers: One at the Busch Post Office (BPO) and one at the MAE Dept. Graduate Office, in room B226. Please use your BPO No. for personal mail. Your mailbox at the MAE Graduate Office is for official Rutgers business only. Any student living on campus is able to obtain a BPO No. If you live off campus, have your personal mail sent to that or to your home address and not to the MAE department.

MAE Bulletin Boards

Important notices are posted on these boards. Please read them regularly.

Student Offices

There is a limited amount of space available for student offices. Priority is given to Teaching Assistants and Graduate Assistants working with faculty on specific research projects. Any remaining office space is assigned to other eligible students, giving preference to fellowship holders, with the understanding that it may be reclaimed at any time for higher priority use.

Please note: It is the Graduate Director's responsibility to assign you office space. The only exception is a lab that is under the supervision of your advisor. You are not allowed to change your office without prior permission from the Graduate Director. If you are moving to a lab that is under the supervision of your advisor, you should notify the graduate office as soon as possible.

Photocopying

If you need to photocopy 15 or less pages related to teaching or research, you can use the copier located in B238. If your research requires extensive use of the copier, please consult your advisor. Materials required by TAs in their instructional duties must be copied through the department office. Please see a staff member for more photocopying details.

Telephones

Use the lab telephones for local calls only. If your research requires that you make long distance phone calls, please see your research advisor for permission to use the phone in B-233. Please keep a list of outside calls made and give the numbers to Wendy in B-235.

Other Important Offices

The Graduate School	Graduate Housing
25 Bishop Place College Avenue Campus 932-7034	581 Taylor Road Busch Campus 445-2215
The Graduate Registrar	**International Services**
Room 200F Administrative Services Building Davidson Road, Busch Campus 445-3556	College Avenue Campus 180 College Avenue 932-7015/7262
Career Services	**English as a Second Language**
46 College Ave, CAC Also at the Busch Campus Ctr 932-7997/7998	Room 107, Tillett Hall Livingston Campus 454-7422
Financial Aid	**Student Accounting**
Room 140, Records Hall College Avenue Campus 932-8811/7057	Records Hall College Avenue Campus 932-7019

If you need assistance for the following concerns, please see the individual indicated:

Concern	Individual
Desk	Secretary, Main Office
Desk keys, telephone	Secretary, Main Office
Facility problems, such as lighting and heating	Laboratory mechanic
Waste disposal and hazard labels	Laboratory mechanic
Supplies:	
Research:	Faculty advisor
Instruction:	Laboratory Director
Repairs of instructional equipment:	
Minor repairs:	TA in charge of course
Extensive repairs:	Laboratory mechanic
Machine Shop work:	
Research:	Faculty advisor
Instruction:	Laboratory Director

Security

1. The doors to the Mechanical Engineering Laboratory, D123, including the doors to instructional rooms should be locked after the last afternoon classes and always on weekends and holidays. If the fire exit doors in D123, D119 or D124 are found unlocked, notify the laboratory technician, the Department Office, or the Laboratory Director. In the evening or on the weekend, notify the University Police, extension 5-7211.
2. The doors to the research laboratories should normally be kept locked, especially those opening to the main corridors.
3. Do not admit unauthorized persons to any of our laboratories after hours or during the weekends or holidays. Do not block doors open.
4. Equipment or supplies should not be removed from the laboratory area unless specifically authorized by the department.

Academic Advising and Advice

Choosing an Advisor

Usually the Graduate Director is assigned to serve as the student's advisor for the first term, except in the case of Graduate Assistants, who are assigned to the faculty member whose research grant is supporting the assistantship.

For Graduate Fellows, Teaching Assistants and other full-time students, the procedure for finding an advisor is as follows. During the first semester at Rutgers, students should inquire about the research currently being done by the faculty of the department to determine research areas of

interest. To do this, the student first will meet with the Graduate Program Director and identify a general area of interest. The Graduate Program Director will then require the student to speak with various faculty members in a specific area to determine possible topics for a thesis or dissertation. After a faculty member has agreed to guide a thesis/dissertation, the student files a form, signed by his/herself and the advisor, with the Graduate Program Director. The faculty member will then become the student's principal advisor. Students are required to determine an area of interest and get the consent of an advisor before the end of the first semester.

Selecting Courses

In determining the courses you plan to take please note that only a subset of our graduate courses is taught every year. Other courses are offered on a 3 to 4 semester cycle. Some advanced courses are offered less regularly. The list of courses offered in a particular semester are posted online in the MAE web site and in the Rutgers Schedule of Classes. These courses will be cancelled if the number of students wishing to take the course is below five. Thus, students who are particularly interested in a given course should register in it during the preregistration period.

Click here for the list of courses offered this academic year. For a typical two year course offering click here. This two year course offering list is intended to be a guide for students to make their study plans for the next two years. Click here for descriptions of all courses.

Please make sure that you satisfy the course requirements in the
M.Eng., M.S. and Ph.D. programs.

Changing Advisors

A related question that sometimes is asked is: How do I change advisors? The question arises, for example, when a student finds that he/she is more interested in a research topic in an area different from the one initially selected. In such cases, the student should contact the Graduate Program Director who, after determining the reason for the desired change, will describe the options available to the student. In most cases, all the student has to do is find a faculty member in the desired area who is willing to serve as an advisor. There are some practical problems associated with these changes. One is the time loss. Another is the possible loss of support for GAs. Neither loss is desirable. Students are encouraged to make their initial selections as carefully as possible. If a change does become necessary, contact the Graduate Director as soon as possible for advice and help.

Extra Work

It should be understood by all students who are supported in any way at Rutgers that we view graduate study to be a full-time activity. This means that all students must have the agreement of their research advisors for any work done, and any courses taken, anywhere. Anyone not following these guidelines is subject to dismissal from the graduate program and subject to actions taken by the University in recovery of costs incurred by the University in support of student's studies.

Description of Graduate Courses

16-650:500 Experimental Methods.
Prerequisites: Undergraduate fluid mechanics and heat transfer

Survey of current measuring techniques used in Mechanical and Aerospace Engineering research; principles of digital and analog data acquisition and reduction.

16-650:504/5 Mathematical Methods in Engineering.
Prerequisites: Undergraduate calculus and differential equations.

Review of matrix algebra; numerical methods for inversion; ordinary differential equations, functions of a complex variable; calculus of variations; partial differential equations and their classification; Fourier methods; asymptotic and perturbation methods.

16-650:510 Computer-Aided Design.
Prerequisite: Limited enrollment; requires permission of instructor.

A broad introduction to Computer-Aided design and Modeling. Mathematical representations of curves, surfaces and solids. Two-and three-dimensional computer graphics. Programming in required for design projects.

16-650:512 Robotics and Mechatronics.
Prerequisite: Undergraduate courses in dynamics, statics, vibrations and controls.

Introduction to robotics and mechatronics including mechanisms and control theories as well as applications; manipulator models; design considerations; control fundamentals; model and sensor based control algorithm development; walking robots; medical and space robotics; experimental mechatronics.

16-650:514 Design of Mechanisms.
Prerequisite: Undergraduate course in kinematics of mechanisms or equivalent.

Complete mechanism design cycle: synthesis, analysis and redesign; analytical, numerical and visualization techniques applied to mechanism synthesis (type, number and dimensional) and analysis; application of optimization methods in the design cycle; planar and spatial mechanisms.

16-650:518 Biomechanical Systems.
Prerequisites: Undergraduate courses in mechanical design and in solid mechanics.

Selected topics from the study of the human body as a mechanical system, with emphasis on modeling, analysis, and design. The biomechanical systems to be investigated are those that are frequently encountered in orthopedic surgery and physical rehabilitation.

16-650:520 Tissue Mechanics.
Prerequisite: Graduate standing in Mechanical/Aerospace Engineering.

Mechanical properties of living soft and hard tissues as explained from their ultrastructural makeup. Function-property relationships of biological tissues and their pathological implications.

16-650:522 Analytical Dynamics.
Prerequisite: Graduate standing in Mechanical/Aerospace Engineering.

Newtonian mechanics; rotating frames; Variational principles; Lagrange's equations, Hamilton's equations, Euler angles, Euler's equations, gyroscopic motion.

16-650:524 Optimal Design in Mechanical Engineering.
Prerequisite: Graduate Standing in Mechanical/Aerospace Engineering

Formulation and solution of engineering optimal design problems in mechanical engineering. Introduction to algorithms for constrained and unconstrained searching. Application to optimal design of mechanical and structural components. Use of discretization techniques; shape optimization problem.

16-650:530 Fluid Mechanics I.
Prerequisite: Undergraduate fluid mechanics.

Physical properties of fluids; basic equations of motion; kinematics; exact solutions of the Navier-Stokes equations; incompressible boundary layer equations and applications; flow past bodies, jets and wakes; introduction to turbulent flows.

16-650:532 Experimental Methods in Fluid Mechanics.
Prerequisite: Undergraduate fluid mechanics.

Experimental and analytical/data tools needed by fluid experimentalists, data acquisition, measurements, model building, optical diagnostics and visualization.

16-650:534 Computational Fluid Dynamics.
Prerequisite: Undergraduate fluid mechanics.

Development and application of computational methods for fluid mechanics based on the incompressible and compressible Navier Stokes equations, boundary layer equations and Euler equations. Selected algorithms including finite difference, finite volume and special techniques. Applications chosen from incompressible and compressible flows.

16-650:550 Mechanics of Materials.
Prerequisites: Undergraduate courses in solid mechanics.

Critical examination and application of the theories and methods for evaluating stresses and deformations of mechanical components and structures under static and dynamic loading.

16-650:554 Mechanics of Continua (Solid Mechanics I).
Prerequisites: Undergraduate mechanics and engineering mathematics.

Introduction to the fundamental concepts of continuum mechanics, including stress and strain, kinematics, balance laws, and material symmetry. Applications to theories of elasticity, plasticity, fracture, viscoelasticity, and classical fluid dynamics.

16-650:556 Theory of Elasticity (Solid Mechanics II).
Prerequisites: 16:642:527 or equivalent.
Corequisite: 16:642:528

The classical theory of linear elasticity. Equations of equilibrium; plane stress; plane strain; Airy stress function; torsion; energy theorems; solutions of selected classical problems.

16-650:570 Conduction Heat Transfer.
Prerequisite: Undergraduate course in heat transfer.

Analytical methods in steady and transient heat conduction in solids; finite difference and finite volume methods in heat conduction.

16-650:574 Thermodynamic Theory.
Prerequisite: Undergraduate thermodynamics.

Principles and methods of thermodynamics, including classical, statistical and irreversible thermodynamics.

16-650:578 Convection Heat Transfer.
Prerequisites: Undergraduate course in heat transfer and 16-650:530 or equivalent.
Forced and free convection in internal and external laminar and turbulent flows; mass transfer; applications.

16-650:582 Computational Heat Transfer.
Prerequisites: Undergraduate fluid mechanics and heat transfer.

Development and application of computational methods for conduction, natural, forced and mixed convection, radiation, traditional and recent conjugate heat transfer and mass transfer. Selected algorithms include finite difference, finite volume, finite element and spectral techniques.

Applications chosen from thermal energy systems, environmental heat transfer, microelectronics packaging, materials processing and other areas.

16-650:601/2 Independent Study.

Prerequisite: Consent of instructor and graduate director.

Independent studies or investigations in a selected area of mechanical and aerospace engineering. The instructor must prepare a syllabus on the subject being studied for the students file.

16-650:604 Advanced Engineering Analysis.

Prerequisites: 16-642:527, 16-650:522 or 16-650:530

Behavior of linear and nonlinear systems; phase-plane analysis; bifurcation; stability criteria; perturbation methods. Examples from fluid mechanics, heat transfer, and dynamics.

16-650:606 Advanced Mechanical Engineering Topics.

Topics of current interest in Mechanical and Aerospace Engineering, such as applications of computer-aided intelligence, computer-aided manufacturing, and waves in fluids.

16-650:608/9 Seminar in Mechanical Engineering.

Prerequisite: Ph.D. Candidacy in Mechanical and Aerospace Engineering, or consent of the Graduate Director.

Lectures by invited speakers, faculty, and graduate students on current research topics in mechanical and aerospace engineering.

16-650:618 Special Applications in Control.

Prerequisites: Graduate background in Mechanical Control Systems and Vibration.

The course is an introductory of nonlinear dynamical systems and control. We will introduce nonlinear phenomenasuch as multiple equilibria, limit cycles, bifurcations, etc. Second-order dynamical systems will be discussed and analyzed using phase plane techniques. Stability of equilibrium points and Lyapunov stability will be discussed. Several nonlinear control techniques, such as feedback linearization, robust and adaptive stabilization and tracking control, and nonlinear estimation, will be introduced and discussed. Applications will be emphasized throughout the class.

16-650:622 Advanced Optimization.
Prerequisite: 16-650:614

Focusing on the mathematical framework of optimization, the course will provide students with in-depth coverage of mathematical programming, probabilistic optimization methods, global optimization, multi-objective optimization and their objectives.

16-650:626 Advanced Design and Fabrication.
Prerequisites: 16-650:514, 614 or equivalent.

Synthesis of design methodologies with application to industrial problems.

16-650:630 Fluid Mechanics II.
Prerequisite: 16-650:530 or equivalent, or permission from instructor
Vortex dynamics of incompressible, inviscid and low viscosity fluids. One, two, and three dimensional compressible flows. Linear, nonlinear acoustic and gravity waves, etc. and shock waves using shock polars. Stability of viscous and inviscid vortex, wave and boundary layer flows. Special Topics: 1) Accelerated Flows: Rayleigh-Taylor and Richtmeyer-Meshkov for supersonic combustion and inertial confinement fusion. 2) Visualization and quantification of evolving flows. 3) turbulent scaling laws.

16-650:631 Fluid Mechanics III.
Prerequisite: 19-650:530 or equivalent, or permission from instructor.

Waves, low reynolds number flows, stratified and inviscid flows.

16-650:634 Compressible Flows.
Prerequisite: 16-650:630 or equivalent.

Linear and nonlinear theory of one-dimensional inviscid unsteady motion, compression and expansion waves, shock tube and wave interactions; two-dimensional inviscid steady motions, including linearized subsonic and supersonic flows; boundary layer theory of compressible fluids.

16-650:636 Turbulence.
Prerequisite: 16:650:530

Physical aspects and methods of analysis of turbulent flows; scaling laws, modeling techniques, and statistical description of turbulence; application to problems in engineering science and geophysical fluid dynamics.

16-650:638 Hydrodynamic Stability.
Prerequisite: 16-650:530 or equivalent.

Thermal, centrifugal and shear instabilities; linear, nonlinear and energy methods.

16-650:640 Acoustics.
Prerequisites: Undergraduate fluid mechanics and 16-642:530 (or concurrent registration in it).

Sound wave propagation in gases and liquids. Reflection and transmission phenomena. Emission and absorption of sound.

16-650:642 Suspensions.
Prerequisites: 16-650:530 or equivalent and one graduate level course in applied mathematics or consent of instructor.

Fluid mechanics of small bubbles, droplets, and rigid particles in fluids. Fluid forces and heat transfer rate. Two-phase fluid dynamics. Applications to aerosols, bubbly liquids, emulsions, and hydrosols.

16-650:651 Mechanics of Inelastic Behavior (Solid Mechanics III).
Prerequisite: 16-650:550 or 16-650:650

Mechanics of inelastic behavior, including Plasticity, Viscoelasticity and Micromechanics. Yield Criteria, flow hardening rules, DruckerÂ's postulates, multi-axial theories, and boundary value problems. Rheological models, creep compliances and relaxation moduli, complex moduli, rheologically simple materials. Dislocation theories, crystal plasticity, EshelbyÂ's solution for an inclusion, mechanics of phase transformation.

16-650:652 Composite Materials, Fracture Mechanics, and Thermoelasticity (Solid Mechanics IV).
Prerequisite: 16-650:554, 16-650:650

Composite materials; anisotropy, elastic constants, stress-strain averages, energy principles, bounds, and micromechanics models. Basics principles of fracture mechanics: mechanisms of fracture and crack growth, energy release rates, complex stress functions, stress intensity, fracture criteria, mixed-mode fracture, dynamic fracture. Thermoelasticity: linear coupled theory, uncoupled theory, solution of selected applied problems involving heat and deformation, application to composite and advanced materials.

16-650:653 Structural Mechanics (Solid Mechanics V).
Prerequisites: 16-650:550, 16-650:554 and 16-650:650 or permission of instructor.

Review of plate theory. Foundations of shell theory. Variational calculus and energy theorems, stability and buckling. Composite structures: anisotropic structures, laminated beams, plates and shells, failure mechanisms.

16-650:654 Dynamics of Solids and Structures (Solid Mechanics VI).

Prerequisites: Undergraduate course in mechanical vibration, and 16-650:550, 16-650:554, and 16-650:650.

Review of multi-degree of freedom vibration. Vibration of continuous systems: strings, beams, membranes and plates. Vibration and waves. Waves in beams and plates. Bulk elastic waves. Reflection and Transmission, Rayleigh surface waves, ultrasonics. Additional topics such as random vibration as time permits.

16-650:660 Finite Element Methods in Solid Mechanics.

Prerequisites: 16-650:554.

General theory, application of finite element methods to the solution of the equations of elasticity viscoelasticity and plasticity. Two-and three-dimensional linear and nonlinear, static and dynamic problems. Computer programs for such problems.

16-650:661 Advanced Mechanical and Random Vibration.

Prerequisite: 16-650:654

Continuous systems, exact and approximate solutions; integral formulation, vibration under combined effects, inclusion principle qualitative and quantitative behavior of the eigensolution, computational techniques. Random vibration of nonlinear oscillators, Markov processes.

16-650:662 Advanced Stress Waves in Solids.

Prerequisite: 16-642:654

Propagation of elastic waves in solids, reflection and transmission, Rayleigh waves, waves in plates, dispersion, radiation from a point load, Fourier transforms methods; scattering; waves in anisotropic materials; propagation of discontinuities; shocks.

16-650:663 Advanced Plasticity.

Prerequisite: 16-650:651

Advanced theories and computational models in plasticity. Crystal plasticity for metallic systems based on dislocation theory and statistical mechanics. Sources of hardening for single and multiple glide conditions. Nucleation and growth of defects induced by plastic deformation. Large-strain constitutive relations for crystalline materials. Numerical implementation into Finite Element formulations.

16-650:664 Advanced Fracture Mechanics.
Prerequisite: 16-650:652

Fracture mechanics; linear elastic, dynamic, elastic-plastic materials and structures. Time dependent; fracture and fatigue crack growth for metals, ceramics, polymers, and composites. Mathematical methods in fracture mechanics; weight functions (3D), Green's functions (dislocation and point force), complex variable methods (2D), integral transforms, and applications of the FEM and BEM.

16-650:665 Advanced Composite Materials.
Prerequisite: 16-650:650

Classification of anisotropy; and elastic constants; particulate, fiber, and disc reinforcements; stress-strain average and energy principles; mean-field theory, self-consistent and generalized self-consistent models method; differential scheme; Hashin-Shtrikman's variational principles, bounding techniques; viscoelastic, plastic, and viscoplastic composites.

16-650:666 Advanced Micromechanics.
Prerequisite: 16-650:650 or 16-650:651

Origins of internal stress, Green's tensor function. Eshelby's solutions of ellipsoidal inclusions; crystal plasticity; continuous distribution of dislocations; single crystal versus polycrystalline; Martensitic transformation in shape-memory alloys, ferroelectric ceramics.

16-650:667 Advanced Stability of Elastic Systems.
Prerequisites: 16-650:554, 16-650:650

Hamilton's principle; discrete and continuous systems; dynamical theories of beams and plates; nonlinear vibrations; Liapunov stability; limit cycles; chaotic motion. Applications include the static and dynamic stability of thin-walled structures.

16-650:668 Advanced Viscoelasticity.
Prerequisite: 16-650:651

Basic rheological models and differential constitutive equations; Boltzman's superposition principle and hereditary integrals, Laplace transform; creep, relaxation, and complex moduli; discrete and continuous spectra; thermorheologically simple materials; glass transition temperature; William-Landel-Ferry (WLF) equation; chronorheologically simple and rheological complex materials; physical aging.

16-650:669 Advanced Thermoelasticity.
Prerequisite: 16:650:652

Formulation and solution of problems involving the effects of temperature on the elastic and inelastic behavior of materials and structures. Thermodynamics of deformation; heat transfer; thermo-elasticity/thermoviscoelasticity.

16-650:670 Combustion.
Prerequisites: Undergraduate courses in thermodynamics and fluid mechanics.

Fundamentals of combustion processes; premixed flames, diffusion flames, one dimensional gas dynamics, thermal explosion theory.

16-650:674 Radiation Heat Transfer.
Prerequisite: Undergraduate course in heat transfer.

Theory of radiant heat transfer; characteristics of ideal and real systems; radiant energy exchange with and without participating media; analytical numerical and experimental techniques; gray and nongray system analysis; secular radiation.

16-650:678 Boiling and Condensation Heat Transfer.
Prerequisites: Undergraduate courses in heat transfer and in fluid mechanics.

A detailed presentation of boiling and condensation heat transfer; nucleate boiling, transitional boiling, film boiling, film condensation, and dropwise condensation.

16-650:682 Thermal Transport in Materials Processing.
Prerequisites: Undergraduate courses in heat transfer and fluid mechanics.

Transport phenomena in processes such as heat treatment, bonding, extrusion, casting, injection molding, crystal growing, metal forming and plastic processing; analysis, mathematical modeling and numerical simulation of such processes for design and optimization of the relevant systems.

16-650:699 ***Nonthesis Study. (N1,N1). Staff.***
16-650:701/2 ***Research in Mechanical and Aerospace Engineering.*** (With Advisor)

DESCRIPTIONS OF RECOMMENDED COURSES TAUGHT BY OTHER DEPARTMENTS

16-198:510 Numerical Analysis.

Prerequisites: Ability to use high-level language such as: FORTRAN IV; a minimum of four terms of undergraduate mathematics including calculus and linear algebra.

Derivation, analysis, and application of methods used to solve numerical problems with computers; solution of equations by iteration, approximation of functions, differentiation and quadrature, differential equations, linear equations and matrices, least squares.

16-332:505 Control System Theory I.

Prerequisite: 16-332:501

Transform theory and transfer function concepts; Nyquist and Bode plots; Nyquist and Hurwitz criterion of stability and design techniques involving Hall and Nichols charts; design of compensating networks via root locus technique; state space formulation of control systems; definition of stability in time domain for general systems; methods of finding stability constraints; discrete systems; z-transforms; difference equations; stability criterion.

16-332:506 Control System Theory II.

Prerequisite: 16-332:505

Review of state space techniques; transfer function matrices, concepts of controllability, observability, and identifiability; identification algorithms for multivariable systems, minimal realization of a system and its construction from experimental data; state space theory of digital systems; design of a three mode controller via spectral factorization.

16-640:509 Topics in Analysis.: Techniques of Asymptotic Analysis.

Prerequisites: Ordinary & Partial Differential Equations & Complex Analogies.

General boundary--layer theory; matched asymptotic expansions, WKB and turning point theory; multiscale expansions; PLK method; maximal balance and other principles of asymptotology; asymptotics beyond all orders

16-642:527, 528 Methods of Applied Mathematics.

Prerequisites: Advanced calculus and ordinary differential equations.

Appropriate topics from linear algebra, linear operators in Hilbert space, linear integral equations, boundary value problems, calculus of variations, numerical solution of ordinary and partial differential equations. One or both of these courses are required of MAE graduate students.