UNIVERSITY of PENNSYLVANIA

MEAM Master of Science in Engineering Program

GUIDELINES FOR GRADUATE STUDY

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Mechanical Engineering and Applied Mechanics
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TABLE OF CONTENTS

1. Introduction 3
2. Administrative Structure 3
3. Advisor(s) 3
4. Degree Requirements 3
5. General Information 4
    - Registration 4
    - Leaves of Absence 4
    - Obsoleteness 4
    - Changes in Course Program 4
    - Grades, Credits and Academic Standing 5
    - Academic Integrity 5
6. Independent Study 5
7. Policy on Transfer of Credit Units Earned at other Institutions 6
8. MSE Thesis 6
9. Transition to the Ph.D. Program 7
10. Attendance at Departmental Seminars and Thesis Presentations 7
11. Submatriculation 7
12. Dual Degree Programs 8
    - Dual Degree in Two Engineering Disciplines 8
    - MBA/MSE Dual Degree Programs 8
13. Summer Studies 8
14. MEAM MSE Merit Scholarship 8
15. Records 8
16. Graduate Environment 8

Appendix A: List of Approved Courses by Concentration Area 9

Appendix B: Hard Cover Instructions for MSE Thesis 15

1. INTRODUCTION

Advances in technology have increased the need for mechanical engineers with more complete knowledge and diverse skills than a typical undergraduate program can provide. As a result, graduates with a Master of Science in Engineering (MSE) degree can look forward to greater job opportunities, more rewarding positions, and higher levels of responsibility than engineers with just a Bachelor's degree. Mechanical engineering, which is one of the broadest engineering disciplines, provides an excellent background for individuals interested in occupations ranging from product research and design to technological management. The Department of Mechanical Engineering and Applied Mechanics (MEAM) at the University of Pennsylvania has designed a flexible MSE Program to prepare students for professional careers and leadership roles in industry while also providing them with the opportunity to strengthen their fundamental knowledge and obtain an exposure to research. In recognition of the interdisciplinary nature of the modern workplace, students who enroll in our MSE program are encouraged to take courses in other departments in the School of Engineering and Applied Science, School of Arts and Sciences and the Wharton School of Business.

The information presented here is not exhaustive; students should also obtain information from the Penn Engineering website: www.seas.upenn.edu/graduate/handbook/index.php

More information, updated from time to time, on the MSE program is also available on the department website, www.me.upenn.edu/current-students/masters/handbook.php. Reading all of the rules and procedures is essential in order to be familiar with various degree requirements and the plentiful opportunities that are available. These guidelines together with the above publications will answer most of your questions. Advice and answers to special questions may be obtained from your advisor or the Master's Program Chair[2], as well as the Graduate Program Coordinator[1], who will assist you in any reasonable manner possible.

Students who matriculated before August 2018 are subject to the policies that were in effect as of their matriculation date.

2. ADMINISTRATIVE STRUCTURE

The Graduate Group in Mechanical Engineering and Applied Mechanics administers the graduate program in MEAM. The Graduate Group is comprised of the primary faculty members of MEAM as well as faculty from other departments and schools throughout the University. This unique composition gives students the opportunity to work in emerging and interdisciplinary areas that are relevant to mechanical engineering. The current members of the MEAM graduate group and their research areas can be obtained from the website: www.me.upenn.edu/about-research/research-matrix.php. Additional information can be obtained from the department website.

All graduate programs in SEAS are administratively under the auspices of the Office of Research and Academic Services, whose activities with respect to graduate studies in MEAM are in conjunction with the recommendations of the MEAM Graduate Group Chair[1] and Master's Program Chair.

3. ADVISOR

The first person with whom a new student has contact is an assigned academic advisor. A program of study is developed with the academic advisor. Later on, if necessary, the student may request a change of advisor, which will be considered and approved by the Master's Program Chair as appropriate. The academic advisor is responsible for monitoring the student's academic plan and, if applicable, thesis work.

4. DEGREE REQUIREMENTS

To earn an MSE degree in Mechanical Engineering and Applied Mechanics (MEAM), a student must complete 10 graduate level courses **and 2 semesters of seminar**. Of the 10 courses, at least five must be MEAM courses, two must be mathematics, and the remaining three are electives. There is one required course for each concentration area (see Appendix A). In addition to the one required course for each concentration area, two additional courses must be selected from the preapproved core requirement list for the student's chosen concentration (Appendix A). The remaining two MEAM courses can be any MEAM graduate course selected by the student in consultation with their advisor. Only graduate level MEAM courses can count towards the MEAM Core Requirement. A concentration area should be chosen and declared before the beginning of the second semester of study. The mathematics courses should be chosen from the approved list in Appendix A. The elective courses should also be chosen from the preapproved elective list for the student's chosen concentration (Appendix A). Advisor approval is required if a student wishes to take an elective course not listed. Elective courses are typically in MEAM or other SEAS departments. Courses taken outside of SEAS should be relevant to the student's career

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goals or to the subdiscipline of interest to the student. Up to two graduate courses may be transferred from other institutions upon the approval of the Master's Program Chair. Students may take up to two independent study courses (MEAM 599). Independent study courses (MEAM 599) must follow the guidelines detailed in section 6 of this manual and may not be counted as part of the required five MEAM courses. Students electing to write a thesis cannot take an independent study course for degree credit.

The MSE concentration areas are:

- Mechatronic and Robotic Systems
- Micro/Nano Systems
- Heat Transfer, Fluid Mechanics, and Energy
- Mechanics of Materials
- Design and Manufacturing

Opportunities are also available for students to customize their concentration with the guidance and approval of their academic advisor. The student and his/her academic advisor should agree upon a program of courses before the student embarks on his/her graduate study.

Appendix A lists the MEAM core, electives and mathematics courses for each concentration area.

Summary of MSE degree Course requirements

Math Requirement	2 ENM* Courses
MEAM Core Requirement	5 MEAM Courses • 1 concentration-specific required core course • 2 additional courses in concentration area • 2 any MEAM (except MEAM 599)
Electives Requirement	3 Courses
Seminar Requirement** (Full time students only)	2 Semesters (Register for MEAM 699)
Total	10 Courses + 2 Seminar

* ENM - Engineering Mathematics
** There is no tuition charge for the MEAM seminar course (MEAM 699)

5. GENERAL INFORMATION

Registration:
All students enrolled in a degree program are required to be continuously registered. Three courses per semester (including independent studies) is considered to be a normal full-time load for all students. Seminar (MEAM 699) courses do not count toward the full-time load. Students in the MSE program may take up to five courses in a semester if they are in excellent academic standing (with a G.P.A. of 3.5 or better), with approval from the academic advisor and Master's Program Chair. Part-time students usually take one or, at most, two courses per semester. The student must obtain his/her advisor's approval for any course selection.

Example:
- Students who successfully complete 3 courses per semester will graduate in 2 years (4 semesters)
- Students who successfully complete 4 courses per semester will graduate in 1.5 years (3 semesters)
- Students who successfully complete 5 courses per semester (approval required) will graduate in 1 year (2 semesters)

Leaves of Absence:
Continuous registration as a graduate student is required unless a formal leave of absence is granted by the Dean of Engineering.

Obsoleteness:
The maximum time allowed for the completion of all MSE requirements is seven years. Course units that are older than seven years may not be counted toward the degree requirements.

Changes in Course Program:
Students may add or drop courses without penalty during a semester if it is done by the deadline listed in the current graduate bulletin. The student must inform the advisor of the decision beforehand and receive his/her approval.

Grades, Credits, and Academic Standing:

The grading system is as follows: A (4.0), Excellent; B (3.0), Good; C (2.0), Fair; D (1.0), Poor; F (0.0), Failure. A course in which an F was obtained must be taken again; however, the F will remain on the student's transcript. In accordance with SEAS policy, "No grade lower than a 'C-' will be counted in courses designated as 'core' courses or those courses must be retaken." Courses for which a passing grade was obtained cannot be retaken for credit.

An incomplete (I) or a no report (NR) are temporary notations and students are allowed a period of one semester to clear. Failure to clear an "incomplete" or "no report" within the allotted time will result in an automatic grade of F. *No students will be permitted to graduate if there are any Incomplete, Unsatisfactory, or No Report notations on their records.*

MSE students in Engineering are expected to maintain at least a B- average (2.7) in their work. A student whose record falls below a B- average will be put on academic probation and may be required to withdraw; graduation requires a B- average minimum (exclusive of thesis and dissertation grades).

Academic Integrity:

Each MEAM student is expected to abide by Penn's Code of Academic Integrity (http://provost.upenn.edu/policies/pennbook/2013/02/13/code-of-academic-integrity). Students should not knowingly use any dishonest method to gain an unfair advantage over other students in academic pursuits, especially through, but not limited to:

- Giving or receiving any unauthorized aid on an assignment or exam, including working in groups on any assignment that has been designated as individual by the professor;
- Misrepresenting the originality of one's work (plagiarism), particularly through direct copying of work and also through failing to note the contributions of others, except as permitted by the instructor;
- Submitting substantially the same work for credit in more than one class, except with prior approval of the instructor.

If there is any doubt as to what is permissible, it is the student's responsibility to ask the instructor. Students caught cheating will be subject to disciplinary action, which may include referral to the Office of Student Conduct. For more information, please see the Student Guide on Academic Integrity: www.upenn.edu/academicintegrity/

6. INDEPENDENT STUDY

Independent study courses (MEAM 599) are important vehicles to accommodate special interests of the students that are not served through the regular courses. They create opportunities for mini-projects and a mentoring relationship between students and faculty. Independent study also can serve as a means for students and faculty to lay a potential foundation for dissertation work prior to making a long-term commitment. The student should identify the topic and scope of the independent study in the semester prior to the one in which s/he intends to take on the independent study, and should identify a faculty advisor whose interests and expertise match the independent study topic.

Since independent studies are less structured than regular courses and typically do not come with strict deadlines, occasionally students tend to fall behind in their work. There is also the possibility of miscommunication between the student and the faculty on the objectives, extent, scope, and the grading method for the independent study.

The purpose of this policy is to set the rules for an independent study with the objectives of maintaining academic rigor and minimizing any potential for a miscommunication.

- An independent study course should require an effort comparable to that of a regular course, about 9 hours a week or a total of 126 hours per semester.
- The student should meet the faculty member administering the independent study (the advisor) on a regular basis, at least once a week. It is the student's responsibility to schedule these weekly meetings. Past experience indicates that failure to maintain regular contact with the student's advisor can lead to a less than satisfactory performance in the independent study course. The key to a successful independent study is a steady effort throughout the semester. The student should not expect to be able to cram a semester's work into a few days of intensive work at the end of the semester.
- Prior to the beginning of the semester in which the student contemplates taking the independent study, the student and his/her advisor should develop an independent study proposal. The first paragraph of the proposal should describe the objectives, scope, and content of the independent study. The second paragraph should state how the independent study will be evaluated and how the student will be graded. The document should be signed by both the student and his/her advisor, and it should be submitted to the Graduate Coordinator, who will convey it to the Master's Program Chair for approval before the beginning of the semester.
- At the conclusion of the independent study, the student should prepare a brief report specifying what material was covered during

the independent study, which objectives were met, and which were not. In the event that objectives were not met, a clear explanation should be provided as to why such objectives were not met. This document should also be signed by the student and his/her advisor, and it will be included in the student's file.

- It is the student's responsibility to make sure that these guidelines are followed. Failure to follow these guidelines may result in the student's not receiving credit for the independent study.

7. POLICY ON TRANSFER OF CREDIT UNITS EARNED IN OTHER INSTITUTIONS

MSE students may obtain credit for up to two courses taken at another institution. These courses are referred to as transfer courses. Transfer courses must be graduate level courses in which at least a B grade has been earned. Transfer credit will only be considered for courses taken prior to matriculation in the graduate program in the Department of Mechanical Engineering and Applied Mechanics. To obtain credit for courses taken at other institutions, the following procedure must be followed:

- For each transfer course, obtain the course description and the title of the textbook used in the course.
- Identify a professor who teaches a similar course at Penn. If a similar course is not offered at Penn, identify a professor whose areas of expertise are in the general area of the course to be transferred. The professor should certify that the course is of similar level to a graduate course offered at Penn or, if a similar course is not offered at Penn, that the course qualifies for Penn students to take if it were offered here.
- Submit a petition on a standard form (www.seas.upenn.edu/graduate/pdf/g-transfer-credit.pdf) to the Graduate Coordinator who will convey it to the Master's Program Chair. Attach to the petition a copy of the transcript, the professor's certification, and documents and information noted in the standard form.

8. MSE THESIS

The majority of MSE students complete an entirely coursework-based degree. There is also an option to complete a thesis-based MSE degree. This option is open only to top MSE students and is subject to availability of advisors with suitable research projects. Students pursuing this option typically take two years to complete the MSE. Students who elect to write a thesis cannot count independent study course units as a part of their 10 course units requirement, but thesis research credits (MEAM 597) may be substituted for up to three courses.

MEAM 597 is the course assigned to thesis research. MEAM 597 can be counted towards the core concentration requirement. One, two or three units of this course of independent research may be undertaken simultaneously. The grading of MEAM 597 is done by the student's thesis advisor. Only grades of "S" (satisfactory), "U" (unsatisfactory) or "I" (incomplete) can be earned in this course.

A full-time MSE student who chooses to write a thesis must choose an advisor and a suitable thesis topic by the beginning of his/her second semester of graduate study. The advisor must be a member of the Mechanical Engineering and Applied Mechanics Graduate Group (www.me.upenn.edu/about-research/research-matrix.php). The Chair of the Graduate Group, in response to recommendations by the student and the student's advisor, will then appoint, at the latest by the middle of the student's second semester, a Thesis Committee consisting of at least three standing faculty members at Penn, one of whom shall serve as the Thesis Committee Chair. The Chair of the committee must be a member of the MEAM Graduate Group. The thesis advisor may not serve as the Thesis Committee Chair.

Examples of a typical objective of an MSE thesis are:

- To advance the state-of-the-art in research.
- To solve new problems with existing tools.
- Development of a new instrument or measurement technique, or a computer program for analysis or advanced design.

The graduate student must submit a written thesis proposal and present it to the Thesis Committee by the end of the second semester of study, at the latest. The proposal should typically contain a statement of the objective of the work, a pertinent state-of-the-art review, the scope of the study, and an outline of the proposed final document. The Thesis Committee will evaluate the proposal and make recommendations on how it can be improved. The Chair of the Thesis Committee will then inform the Graduate Group Chair, in writing, about the Committee's evaluation of the proposal. The student must obtain the Thesis Committee's approval of the thesis proposal by the end of the student's second semester.

The thesis must be prepared and submitted following the general SEAS and University of Pennsylvania instructions. Instructions for preparation of the thesis can be found by visiting the following website: https://provost.upenn.edu/uploads/media_items/mastersstyleguide.original.pdf. When the thesis has been approved by the student's thesis advisor, a copy of the thesis must be given to each member of the Thesis Committee, who will then review it. The student must

allow sufficient time for the review (at least two weeks). If the Committee feels that the thesis is suitable for presentation, the student may then schedule a thesis defense. The defense is a public presentation of the work; after this presentation, the Thesis Committee will give final approval or disapproval. The announcement of the presentation to the public must be submitted to the Graduate Coordinator for posting at least two weeks prior to the presentation.

All of the requirements of the thesis must be satisfied and approved before the thesis submission date specified by the Office of Research and Academic Services. When final approval of the thesis is obtained, an original and a photocopy of the thesis must be submitted to the Office of Research and Academic Services, 111 Towne Building prior to commencement, by the date specified. Both copies must be unbound and they must have original signatures. Additionally, a hardbound copy of the thesis (prepared according to instructions in Appendix B) must also be submitted to both the Graduate Group Chair of Mechanical Engineering and Applied Mechanics and to the thesis advisor. Failure to follow the above schedule and requirements will result in a delay in awarding the degree.

9. TRANSITION TO THE Ph.D. PROGRAM

MSE students who are interested in pursuing a Ph.D. after the completion of their MSE degree program should apply via the regular Ph.D. application process by the posted deadline. Current students can request an application fee waiver and request that official transcripts and test scores be transferred from their masters application to their Ph.D. application. For more information, please contact the Graduate Program Coordinator via e-mail. Advanced master's students can petition the Graduate Group Chair to take the Ph.D. qualifier exam as a fast track option – this is rare, but petitions for this will be considered. For more information, please contact the Graduate Group Chair. Complete details are available in the Ph.D. Guidelines.

10. ATTENDANCE AT DEPARTMENTAL SEMINARS AND THESIS PRESENTATIONS

The attendance of all full-time graduate students at departmental seminars is mandatory. There are many good reasons why students should attend departmental seminars even when the seminars are not directly linked to their areas of research. For example:

- The seminar provides an opportunity to learn about the state-of-the-art in MEAM.
- The seminar provides an opportunity for the student to get acquainted with people from other institutions and companies and get an inside view of the culture at other institutions. On more than one occasion, during job interviews, interviewers have been known to mention a visit to Penn and delivering a seminar. The student would like to be in a position to comment on that particular seminar and state how enjoyable it was.
- The departmental seminars are an excellent opportunity to get together as a department. It is hoped that a full attendance at these seminars will help create departmental spirit and cohesiveness.

Seminar Course

The seminar course (MEAM 699) has been established so that students are recognized for their seminar attendance as well as to encourage students to attend. There are no quizzes, tests, or homeworks. There is also NO tuition charged for MEAM 699. The course is graded S/U and does NOT count towards full time enrollment status. Full-time students should take three courses in addition to the MEAM seminar. In order to obtain a satisfactory (S) grade, the student must attend more than 70% of the departmental seminars. For example, in a term in which 12 seminars are given, the student will need to attend at least 9 seminars to obtain a satisfactory grade. Participation in the seminar course will be documented and recorded in the student's transcript. In order to obtain their degree, MSE students will be required to accumulate 2 seminar courses (typically taken in the first two semesters of study). Under special circumstances, e.g., in a case of a conflict with a course offering, the student may waive the seminar requirement for the particular semester by petitioning to the Master's Program Chair. Part-time students are exempted from the seminar attendance requirement although they are encouraged to attend the seminars. Submatriculant students are considered to be full-time and therefore are required to fulfill the seminar requirement prior to graduation.

11. SUBMATRICULATION

Outstanding undergraduate students at the university may submatriculate in the MSE degree program and take graduate-level courses as electives during their junior and senior years. After fulfilling the requirements of both programs, the student will receive a BSE and a MSE degree. Undergraduates at the University of Pennsylvania may double-count up to three graduate-level courses towards both the undergraduate and the graduate degree. The MSE degree may be completed in one to two extra semesters of study. In order to complete both degrees in only four and one-half years, students can consider:

- Taking independent study courses in the summer of the fourth year (up to 2 course units of study),
- Taking five courses in the final term,
- Taking extra graduate-level courses (cannot be counted towards the B.S.E. degree) during the undergraduate program.

Students enrolled as a submatriculant can only count graduate courses taken at Penn towards the master's degree. No transfer credit, study abroad, or study away courses will be accepted.

Submatriculation applications (www.seas.upenn.edu/undergraduate/pdf/ug-appl-submatriculation.pdf) must be submitted by the end of the junior year.

12. DUAL DEGREE PROGRAMS

Dual Degree in Two Engineering Disciplines

Students may enroll in a dual degree program and receive an MSE degree in Mechanical Engineering and any of the other disciplines in the Engineering School such as Electrical and Systems Engineering, Bioengineering, Computer Science, Chemical and Biomolecular Engineering, and Materials Science and Engineering. The dual degree program requires the completion of at least 16 courses and satisfaction of the MSE requirements of each department in which the student wishes to major. This program typically requires five semesters to complete. To enroll in this program, the student must complete an application form, listing the course plan for both programs and obtain the approval from the Graduate Group Chair of each department. Applications for this program are available via the following website: www.seas.upenn.edu/graduate/advising/documents/g-apply-for-dual-masters.pdf.

MBA/MSE Dual Degree Programs

The Mechanical Engineering Department and the Wharton School of Business Administration are committed to the education of excellent managers and engineers who will contribute significantly to the challenges faced by industry. This program leads to two degrees: Master of Business Administration (MBA) and Master of Science in Engineering (MSE). Typically, the program requires 5 semesters of study. To participate in the MBA/MSE Dual Degree Program, the student must apply to, be accepted by, and meet all the requirements of both schools: the Graduate School of Business and the School of Engineering and Science. This requires separate applications to both schools.

13. SUMMER STUDIES

There are several possibilities for scholarly activities by graduate students at the University during the summer which include:

- Independent study and research (MEAM 599 or 597) with an instructor willing to act as a supervisor during the summer.
- Course work outside SEAS, as well as a limited number of regular courses occasionally offered by some SEAS departments. The advisor, in consultation with the Master's Program Chair, must approve summer school courses.

Questions on summer session registration should be referred to the Graduate Coordinator.

14. MEAM MSE MERIT SCHOLARSHIP

The MEAM MSE Merit Scholarship recognizes students with outstanding academic records who are interested in independent research. The MEAM department awards several scholarships each year. These scholarships are typically awarded as tuition credit. First year students apply in the spring semester and, if awarded, the tuition credit is given in the second year of the program. Applications are due in the spring semester. More information will be sent via e-mail near the beginning of the spring semester.

15. RECORDS

The official graduate student records are kept in 111 Towne Building; transcripts can be viewed on Penn InTouch at https://portal.apps.upenn.edu/penn_portal/intouch/splash.html Graduate students are encouraged to periodically check the accuracy of their records and to bring any discrepancies to the attention of the Master's Program Chair.

16. GRADUATE ENVIRONMENT

The size of the Department of Mechanical Engineering and Applied Mechanics fosters a close interaction between the graduate students and the entire faculty. Every effort is made to create an environment of scholarship, creativity and learning, which is the very essence of graduate study. This enhances the quality of student-faculty communications and enriches the academic environment to benefit both learning and discovery. The Department strongly supports the Mechanical Engineering Graduate Association (MEGA). MEGA is a student-run association that represents the entire graduate student community in MEAM, and organizes both social and technical events. A chosen representative of MEGA will be invited, if appropriate, to attend Graduate Group meetings to serve as a communication channel for information between the Graduate Group and students.

APPENDIX A

List of approved mathematics courses (all concentrations)

MATHEMATICS REQUIREMENTS

All MSE students are required to take at least two mathematics courses. Mathematics courses must be selected from the following list. Prior approval from the Master's Program Chair is required if a student would like to take a course other than the ones listed below to satisfy the math requirement.

Course	Title	Typically Offered
ENM 510	Foundations of Engineering Mathematics I	Fall semester only
ENM 502	Numerical Methods and Modeling	Spring semester only
ENM 503	Introduction to Probability and Statistics	Fall & Summer semester
ENM 511	Foundations of Engineering Mathematics II	Spring semester only
ENM 512	Nonlinear Dynamics and Chaos	Spring semester only
ENM 531	Data Driven Modeling	Spring semester
ENM 540	Topics in Computational Science & Engineering	Every other spring semester, next offering planned for Spring 2020
ENM 600	Advanced Engineering Mathematics	Rarely offered
ENM 601	Special Topics in Engineering Mathematics	Rarely offered
MEAM 527	Finite Element Analysis[3]	Fall and Spring semester
CIS 520	Machine Learning[2]	Fall semester

[3] This course can **NOT** be double-counted for both the math and core elective requirement.

List of approved courses for students concentrating in

MECHATRONIC AND ROBOTIC SYSTEMS

Ongoing effort in mechanical systems focuses on modeling and controlling dynamical systems, especially as applied to mechatronic and robotic systems. The graduate courses provide students with a firm theoretical foundation and the interdisciplinary experimental skills that are necessary for dealing with modern-day complex systems. Much of our work involves collaborations with Computer and Information Science and Electrical and Systems Engineering, as well as the Wharton School of Business Administration.

Course	Title	Typically Offered
Required Course		
MEAM 510	**Design of Mechatronic Systems**	**Fall semester only**
Preapproved Core Requirement Courses (choose at least two from the list below)		
MEAM 513	Control of Systems	Spring Semester
MEAM 516	Advanced Mechatronic Reactive Spaces	Rarely Offered
MEAM 517	Control and Optimization with Applications in Robotics	Fall Semester
MEAM 520	Introduction to Robotics	Fall Semester
MEAM 528	Advanced Kinematics (rarely taught)	Rarely Offered
MEAM 535	Advanced Dynamics	Fall Semester
MEAM 543	Performance and Design of Unmanned Aerial	Fall Semester
MEAM 550	Design of Microelectromechanical Systems	Every other spring semester, next offering planned for Spring 2020
MEAM 613	Nonlinear Control Theory	Rarely Offered
MEAM 620	Advanced Robotics	Spring Semester
MEAM 625	Haptic Interfaces	Rarely Offered
MEAM 692	Topics in Mechanical Systems	Offerings Vary
Choose 2 more MEAM graduate level courses		
Preapproved Electives Requirement Courses (choose 3 from list below or any graduate level MEAM course)		
EAS 507	Intellectual Property and Business Law for Engineers	Fall and Spring Semester
EAS 512	Engineering Negotiation	Fall and Spring Semester
EAS 545	Engineering Entrepreneurship I	Fall and Spring Semester
EAS 546	Engineering Entrepreneurship II	Fall and Spring Semester
EAS 595	Foundations of Leadership	Spring Semester
ESE 500	Linear Systems Theory	Fall Semester
ESE 504	Introduction to Optimization Theory	Fall Semester
ESE 519	Real-Time Embedded Systems	Fall Semester
ESE 531	Digital Signal Processing	Spring Semester
ESE 540	Engineering Economics	Fall Semester
ESE 543	Human Systems Engineering	Fall Semester
ESE 650	Learning in Robotics	Spring Semester
CIS 520	Machine Learning	Fall and Spring Semester
CIS 521	Fundamentals of AI	Fall Semester
CIS 540	Principles of Embedded Computation	Last offered in Spring 17
CIS 580	Machine Perception Development	Spring Semester
CIS 581	Computer Vision and Computational Photography	Fall Semester
CIT 590	Programming Languages and Techniques	Fall Semester
IPD 501	Integrated Computer-Aided Design, Manufacturing and Analysis	Spring Semester

Advisor approval is required if a student wishes to take an elective graduate course not on the above list.

List of approved courses for students concentrating in

MICRO/NANO SYSTEMS

Micro/Nano systems is a broad field encompassing the design, development, and fabrication of devices and systems that derive unique functionality due to the small size of key components within them. Examples of such systems include microelectromechanical systems (MEMS), nanoelectronic devices, and microfluidics. Mechanical Engineering plays a central role in all of these systems, such as the mechanical design of MEMS-based sensors and the understanding of heat transfer in nanoelectronics. The graduate courses in this area of concentration provide students with a solid theoretical foundation, knowledge of micro/nano-fabrication techniques, and skills to design micro/nano systems.

Course	Title	Typically Offered
Required Course		
MEAM 537	Nanomechanics and Nanotribology at Interfaces	Spring Semester
Or		
MEAM 550	Design of Mictroelectromechanical Systems	Every other spring semester, next offering planned for Spring 2020
Preapproved Core Requirement Courses (choose at least 2 from the list below)		
MEAM 505	Mechanical Properties of Macro/Nanoscale Materials	Spring Semester
MEAM 507	Fundamentals of Materials	Fall Semester
MEAM 519	Elasticity and Micromechanics of Materials	Fall Semester
MEAM 527	Finite Element Analysis (This course cannot be double-counted for both the math and core requirement.)	Fall and Spring Semester
MEAM 537	Nanomechanics and Nanotribology at Interfaces	Spring Semester
MEAM 550	Design of Mictroelectromechanical Systems	Every other spring semester, next offering planned for Spring 2020
MEAM 553	Atomic Modeling in Materials Science	Spring Semester
MEAM 555	Nanoscale Systems Biology	Fall Semester
MEAM 564	The Principles and Practice of Microfabrication Technology	Fall Semester, next offering Fall 2019
MEAM 572	Micro/Nanoscale Energy Transport	Rarely Offered
MEAM 575	Micro and Nano Fluidics	Fall Semester
MEAM 580	Electrochemistry for Energy, Nanofabrication, and Sensing	Spring Semester
Choose two more MEAM graduate level courses		
Preapproved Electives Requirement Courses (choose 3 from list below or any graduate level MEAM course)		
EAS 507	Intellectual Property and Business Law for Engineers	Spring Semester
EAS 512	Engineering Negotiation	Fall and Spring Semester
EAS 545	Engineering Entrepreneurship I	Fall and Spring Semester
EAS 546	Engineering Entrepreneurship II	Fall and Spring Semester
EAS 547	High Tech. Ventures (rarely taught)	Rarely Offered
EAS 548	High Tech. Venture Development	Rarely Offered
EAS 595	Foundations of Leadership	Spring Semester
ESE 521	The Physics of Solid State Energy Devices	Spring Semester
ESE 536	Nanofabrication and Nanocharacterization	Spring Semester
MSE 520	Structure of Materials	Spring Semester
MSE 525	Nanoscale Science and Engineering	Fall Semester
MSE 565	Fabrication and Characterization of Nanostructured Devices	Spring Semester

Advisor approval is required if a student wishes to take an elective graduate course not on the above list.

List of approved courses for students concentrating in
HEAT TRANSFER, FLUID MECHANICS, AND ENERGY SCIENCE AND ENGINEERING

Aerospace engineering, materials fabrication and manufacturing, cooling of microelectronic equipment, energy conversion and power generation, and thermal control and treatment of living organisms are critically important in today's economy. Our program in heat transfer, fluid mechanics, and energy is designed to provide the basic tools for dealing with these and other problems of current and future technological interest. The program maintains close collaboration with the departments of Chemical Engineering, Bioengineering, Electrical and Systems Engineering, and Materials Science.

Course	Title	Typically Offered
Required Course		
MEAM 536	Viscous Fluid Flow	Spring Semester
Or		
MEAM 570	Introduction to Transport	Fall Semester
Preapproved Core Requirement Courses (choose at least 2 from the list below)		
MEAM 502	Energy Engineering in Power Plants and Transportation Systems	Fall Semester
MEAM 503	Direct Energy Conversion: From Macro to Nano	Fall Semester
MEAM 504	Tribology	Fall Semester
MSE 525	Nanoscale Science and Engineering	Fall Semester
MEAM 527	Finite Element Analysis (This course cannot be double-counted for both the math and core requirement.)	Fall and Spring Semester
MEAM 536	Viscous Fluid Flow	Spring Semester
MEAM 538	Turbulence	Spring Semester
MEAM 530	Continuum Mechanics	Spring Semester
MEAM 545	Aerodynamics	Spring Semester
MEAM 561	Thermodynamics: Foundations, Energy, Materials	Spring Semester
MEAM 570	Introduction to Transport	Fall Semester
MEAM 571	Advanced Transport	Rarely Offered
MEAM 575	Micro and Nano Fluidics	Fall Semester
MEAM 580	Electrochemistry for Energy, Nanofabrication, and Sensing	Spring Semester
MEAM 642	Advanced Fluid Mechanics (rarely offered)	Spring Semester, last offered in Spring 2016
MEAM 646	Computational Mechanics	Spring Semester, last offered in Spring 2017
MEAM 647	Foundations of Complex Fluids (rarely offered)	Rarely Offered
MEAM 662	Advanced Molecular Thermodynamics	Fall Semester
Choose two more MEAM graduate level courses		
Preapproved Electives Requirement Courses (choose 3 from list below or any graduate level MEAM course)		
CBE 545	Elec. Energy Conv. & Storage	Fall Semester
CBE 546	Fundamentals of Industrial Catalytic Processes	Spring Semester
CBE 617	Control of Nonlinear Systems	Fall Semester, last offered in Fall 2015
CBE 618	Advanced Molecular Thermodynamics	Fall Semester
CBE 640	Transport Processes I	Fall Semester
CBE 641	Transport Processes	Spring Semester
EAS 501	Energy and Its Impacts	Fall Semester
EAS 502	Renewable Energy And Its Impacts: Technology, Ecology, Economics, Sustainability	Every other Spring Semester, next offering planned for Spring 2020
EAS 507	Intellectual Property and Business Law for Engineers	Fall and Spring Semester
EAS 512	Engineering Negotiation	Fall and Spring Semester
EAS 545	Engineering Entrepreneurship I	Fall and Spring Semester
EAS 546	Engineering Entrepreneurship II	Fall and Spring Semester
EAS 547	High Tech. Ventures	Rarely Offered
EAS 548	High Tech. Venture Development	Rarely Offered

EAS 595	Foundations of Leadership	Spring Semester
ENGR 503	Engineering in Oil, Gas and Coal, from Production to End Use	Spring Semester
MSE 545	Materials for Energy Storage and Generation	Fall Semester
MSE 555	Environmental Degradation of Materials	Fall Semester

Advisor approval is required if a student wishes to take an elective graduate course not on the above list.

List of approved courses for students concentrating in
MECHANICS OF MATERIALS

The development of new technologies often depends critically on the availability of materials systems capable of withstanding extreme thermomechanical loading conditions. Current examples are provided by the development of advanced engines in the aerospace industry and the design of microchips that are resistant to thermal cycling in the microelectronics industry. In addition, new technologies, such as biomedical technologies, often require the development and understanding of completely new classes of materials systems. The Penn MEAM MSE in Mechanics of Materials is designed to provide the fundamental tools needed to tackle these and other problems of current and future technological interest. These include basic courses in continuum mechanics, elasticity, and plasticity, as well as more advanced ones in fracture, composite materials, biomechanics, and atomistic modeling of materials. The program maintains close collaborations with the Material Science Department and with the bio-medical community.

Course	Title	Typically Offered
Required Course		
MEAM 519	Introduction to Elasticity	Fall Semester
Preapproved Core Requirement Courses (choose at least 2 from the list below)		
MEAM 504	Tribology	Fall Semester
MEAM 505	Mechanical Properties of Macro/Nanoscale Materials	Spring Semester
MEAM 507	Fundamentals of Materials	Fall Semester
MEAM 508	Materials and Manufacturing for Mechanical Design	Spring Semester (not offered every spring)
MEAM 527	Numerical and Finite Element Methods (This course cannot be double-counted for both the math and core requirement.)	Fall Semester
MEAM 530	Continuum Mechanics	Spring Semester
MEAM 537	Nanomechanics and Nanotribology at Interfaces	Spring Semester
MEAM 553	Atom Mod in Mats Science	Spring Semester
MEAM 554	Mechanics of Materials	Rarely Offered
MEAM 555	Nanoscale Systems Biology	Fall Semester
MEAM 631	Advanced Elasticity	Rarely Offered
MEAM 632	Plasticity	Rarely Offered
MEAM 633	Fracture Mechanics	Rarely Offered
MEAM 634	Rods & Shells	Rarely Offered
MEAM 635	Composite Materials	Rarely Offered
MEAM 663	Entropic Forces in Biomechanics	Rarely Offered
Choose 2 more MEAM graduate level courses		
Preapproved Electives Requirement Courses (choose 3 from list below or any graduate level MEAM course)		
EAS 504	Fundamental Concepts of Nanotechnology	Rarely Offered
EAS 507	Intellectual Property and Business Law for Engineers	Fall and Spring Semester
EAS 512	Engineering Negotiation	Fall and Spring Semester
EAS 545	Engineering Entrepreneurship I	Fall and Spring Semester
EAS 546	Engineering Entrepreneurship II	Fall and Spring Semester
EAS 595	Foundations of Leadership	Spring Semester

Advisor approval is required if a student wishes to take an elective graduate course not on the above list.

List of approved courses for students concentrating in

DESIGN AND MANUFACTURING

Global business trends have created a demand for companies to rapidly develop new products at lower costs. In response to these demands companies have been exploring new methods to decrease costs, increase productivity, and create innovative products. In keeping with the needs of local industry the graduate courses below prepare students for careers in Product Design and Manufacturing. Students in the program will study topics such as mechatronics, CAD, computer graphics, industrial design, product design, materials engineering, manufacturing processes, assembly, tolerances, design analysis, plant/process modeling and design, robotics, electrical systems, mechanical systems, controls, intellectual property, and management skills. Graduates of the program will be prepared to be leaders in global manufacturing environment. Much of our work involves collaborations with, among others, the Departments of Computer and Information Science, Electrical and Systems Engineering as well as the School of Design and the Wharton School of Business Administration.

Course	Title	Typically Offered
Required Course		
MEAM 514	**Design for Manufacturability**	**Spring Semester**
Preapproved Core Requirement Courses (choose at least 2 from the list below)		
MEAM 504	Tribology	Fall Semester
MEAM 508	Materials and Manufacturing for Mechanical Design	Spring Semester
MEAM 510	Mechatronics	Fall Semester
MEAM 516	Advanced Mechatronics	Rarely Offered
MEAM 527	Numerical and Finite Element Methods (This course cannot be Double-counted for both the math and core requirement.)	Fall Semester
MEAM 537	Nanomechanics and Nanotribology at Interfaces	Spring Semester
MEAM 543	Performance, Stability & Control of UAVs	Fall Semester
MEAM 550	Design of Micro-Electro-Mechanical Systems	Spring Semester
MEAM 625	Haptic Interfaces (rarely taught)	Rarely Offered
MEAM 564	The Principles and Practice of Microfabrication Technology	Fall Semester
Choose 2 more MEAM graduate level courses		
Preapproved Electives Requirement Courses (choose 3 from list below or any graduate level MEAM course)		
ARCH 726	Furniture Design	Spring Semester
CIS 510	Curves & Surface: Theory & Applications	Rarely Offered
CIS 560	Computer Graphics	Fall Semester
EAS 507	Intellectual Property and Business Law for Engineers	Fall and Spring Semester
EAS 512	Engineering Negotiation	Fall and Spring Semester
EAS 545	Engineering Entrepreneurship I	Fall and Spring Semester
EAS 546	Engineering Entrepreneurship II	Fall and Spring Semester
EAS 547	High Tech. Ventures	Rarely Offered
EAS 548	High Tech. Venture Development	Rarely Offered
EAS 595	Foundations of Leadership	Spring Semester
ESE 536	Nanofabrication and Nanocharacterization	Spring Semester
IPD 501	Integrated Computer Aided Design	Spring Semester
IPD 504	Rehab Engineering & Design	Fall Semester
IPD 511	Creative Thinking and Design	Rarely Offered
IPD 515	Product Design	Fall and Spring Semester
IPD 525	Ergonomics/Human Factors Based Product Design	Fall Semester
IPD 527	Industrial Design I	Spring Semester

Advisor approval is required if a student wishes to take an elective graduate course not on the above list.

APPENDIX B

Hard Cover Instructions
for MSE Thesis

Guidelines:

In addition to the unbound copies that must be given to the Office of Research and Academic Services, one hardbound copy of each MSE thesis must be submitted to the Graduate Group Chair in MEAM and one hardbound copy must be submitted to the student's thesis advisor.

There is a charge of $25.00 per copy. Please check with the Graduate Program Coordinator for more information about hard binding your thesis or dissertation.

MSE dissertations are to be bound in a black cover with gold letters.

The lettering on the front should look like the following example:

Alfred E. Neuman

Design Optimization and Control of a Multi-robot System to Study the Size-Dependent Effects in the Mechanics of Muscle Cells Flowing Through Heated Micro Conduits

MSE Thesis
Mechanical Engineering and Applied Mechanics
University of Pennsylvania
2018

_____
Typed Name
Supervisor of Thesis

_____
Typed Name
Graduate Group Chair