UNIVERSITY of PENNSYLVANIA

M.S.E. PROGRAM

GUIDELINES FOR GRADUATE STUDY

September 2008

Department of Mechanical Engineering
and Applied Mechanics
School of Engineering and Applied Science
229 Towne Bldg., 220 S. 33rd Street
Philadelphia, PA 19104-6315

http://www.me.upenn.edu/graduate/mseguidelines.html

Mechanical Engineering and Applied Mechanics

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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 an M.S.E. 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 Mechanical Engineering and Applied Mechanics Department (MEAM) at the University of Pennsylvania has designed a flexible M.S.E. 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 M.S.E. 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 copies of the following publications (can be obtained from 111 Towne Building; when in print):

- Current University of Pennsylvania catalog "Graduate Study in Engineering and Applied Science."
- "The PennBook - Resources, Policies & Procedures Handbook," which contains University policies and procedures.
- "An Insider's Guide to Graduate Requirements," published by the Office of Graduate Education and Research in the School of Engineering and Applied Science (SEAS).
- "The Practical Penn: A Student Guide" a very informative handbook distributed to all new students.

More information, updated from time to time, on the M.S.E. program is also available on the department website, http://www.me.upenn.edu/graduate/mse.html. 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 Graduate Group Chair[1], as well as the Graduate Program Coordinator[2], who will assist you in any reasonable manner possible.

2. ADMINISTRATIVE STRUCTURE

The Graduate Group in Mechanical Engineering and Applied Mechanics administers the graduate program in Mechanical Engineering and Applied Mechanics. 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 are listed in Appendix D. Additional information can be obtained from the department website.

[1]Dr. Pedro Ponte Castañeda, Room 235 Towne Bldg. (Tel. 215-898-5046, email: ponte@lrsm.upenn.edu)

[2]Maryeileen Banford, Room 297 Towne Bldg. (Tel. 215-898-2826, email: banford@seas.upenn.edu)

All graduate programs in SEAS are administratively under the auspices of the Associate Dean for Academic Affairs[3], whose activities with respect to graduate studies in MEAM are in conjunction with the recommendations of the MEAM Graduate Group 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 Graduate Group Chair as appropriate. The academic advisor is responsible for monitoring the student's academic plan and thesis work.

4. DEGREE REQUIREMENTS

To earn an M.S.E. degree in Mechanical Engineering and Applied Mechanics (MEAM), a student must complete 10 graduate level courses. Of the 10 courses, at least five must be MEAM courses, and three of the five must be in the student's chosen concentration area. Up to two courses may be transferred from other institutions upon the approval of the Graduate Group Chair. The M.S.E. degree can be completed in one year of full-time study. A Master's thesis can be substituted for up to three courses. Students who do not choose to write a thesis may take up to two independent study courses. The independent study course (MEAM 899) must follow the guidelines detailed in section 6 of this manual. The Independent study courses (MEAM 899) may not be counted as part of the required five MEAM courses without prior approval from the Graduate Group Chair.

M.S.E. candidates will choose to concentrate in one of the following areas:

- Design and Manufacturing
- Mechanical Systems: Robotics, and Micro Electro Mechanical Systems (MEMS)
- Heat Transfer and Fluid Mechanics with applications in energy production, material processing, and the electronics industry
- Mechanics of Materials
- Biomechanics
- Opportunities are also available for students to customize their program 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 may embark on his/her graduate study.

M.S.E. students in excellent academic standing (GPA of 3.5 or better) may take up to five courses each semester. All M.S.E. students are required to take two mathematics (ENM) courses chosen from a pre-approved list (see Appendix A). The remaining courses may be chosen from the appropriate pre-approved list for the chosen concentration area (see Appendix A), in consultation with the student's academic advisor.

Summary of M.S.E. degree Course requirements

Math Requirement	2 Courses
MEAM Core Requirement	5 Courses

[3] Dr. R. Vijay Kumar, Room 111 Towne Bldg. (Tel. 215-898-3630, e-mail: kumar@central.cis.upenn.edu)

Electives Requirement	3 Courses
Seminar Requirement *Full time students only	2 Semesters
Total	10 Courses

The program is flexible, crosses disciplinary boundaries, and takes advantage of the opportunities a unique university like Penn has to offer.

5. GENERAL INFORMATION

Registration:
All students enrolled in a degree program are required to be continuously registered. Three courses per semester (including thesis research, such as MEAM 999 and independent studies) is considered to be a normal full-time load for all students. Students in the M.S.E. 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). Approval from the Graduate Group Chair or academic advisor is necessary if the student wants to take more than four courses in their first semester. Students must always consult with the Graduate Group Chair if a deviation from the normal load is being contemplated or desired. Part-time students usually take one or, at most, two courses per semester.

MEAM 999 is the course assigned to thesis/dissertation research. One, two or three units of this course of independent research may be undertaken simultaneously. The grading of MEAM 999 is done by the student's thesis advisor. Only grades of "S" (satisfactory), "U" (unsatisfactory) or "I" (incomplete) can be earned in this course. First year students must complete an advisor's sign-off form. This form may be found in Appendix E and should be submitted prior to registering for courses.

Leaves of Absence:
Continuous registration as a graduate student is required unless a formal leave of absence is granted by the dean of the student's school. A student who has reached dissertation tuition status will not be granted a leave of absence, except for military duty, medical reasons, or when a student receives a grant for dissertation research abroad and the grant does not include funds to pay home institution fees. A student not in dissertation status who desires a leave of absence must submit a request to the Graduate Group Chair and to the Graduate Division Office.

Obsoleteness:
The maximum time allowed for the completion of all M.S.E. 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. 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. Grades of S (Satisfactory) and U (Unsatisfactory) are given for MEAM 999. *No students will be permitted to graduate if there are any Incomplete, Unsatisfactory, or No Report notations on their records.*

Students in the school 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).

6. INDEPENDENT STUDY

Independent study courses are important vehicles to accommodate special interests of the students, which are not served through the regular courses. They create opportunities for mini-projects and a mentoring relationship between the student and the faculty. Independent study also can serve as a means for the student and advisor to appreciate each other's interests and get started on 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.

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. In the absence of regular contact, the student stands the risk of not being focused leading to an impression of dereliction. 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 a brief document. The first paragraph of the document 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 group 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, those objectives that were met and those that 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 not receiving credit for the independent study.

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

M.S.E. 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 prescribed for 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 (appendix C) to the Graduate Group Chair. Attach to the petition a copy of the transcript, the professor's certification, and documents and information noted in Appendix C.

8. M.S.E. THESIS

The M.S.E. thesis is optional and it may substitute for up to three courses. Students who elect to write a thesis cannot count independent study course units as a part of their 10 course units requirement.

A full time M.S.E. student who chooses to write a thesis must choose an advisor and a suitable thesis topic by the end of his/her first semester of graduate studies. The advisor must be a faculty member of the Mechanical Engineering and Applied Mechanics Graduate Group (see Appendix D). 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 end of the student's first semester, a Thesis Committee consisting of at least two faculty members, one of whom shall serve as the Thesis Committee Chair. The thesis advisor may not serve as the Thesis Committee Chair.

Examples of a typical objective of an M.S.E. thesis are:

- To advance the state-of-the-art in research.
- To solve new problems with existing tools.
- Critical, analytical review of the state-of-the-art in a given field.

- 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 at the latest during the second semester of study. The proposal should typically contain a statement of the objective of the work, a pertinent state-of-the-art review, the scope of the studies, 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 for this purpose. Instructions for preparation of the thesis can be obtained from the Academic Programs Office, 111 Towne Building. 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). A public presentation of the work is then made; 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 Group Chair 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 the Associate Dean for Academic Affairs. When final approval of the thesis is obtained, an original and a photocopy of the thesis must be submitted to the Associate Dean for Academic Affairs, 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 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

The M.S.E. students who are interested in pursuing a Ph.D. after the completion of their program should inform the Graduate Group Chair of this intention. Students who aspire to continue for the Ph.D. degree must maintain a GPA of 3.0 or above, and take and pass an exam, which serves as an important component of determining their ability to independently conduct research of high quality.

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 mechanical engineering and applied mechanics.
- 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 has been established so that students are regognized for their seminar attendance as well as to encourage students to attend. There are no quizzes, tests, or homeworks. The course is graded S/U. 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, M.S.E. students will be required to accumulate 2 seminar courses (beginning in the fall of 2001). 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 Graduate Group Chair. Part-time students are exempted from the seminar attendance requirement although they are encouraged to attend the seminars.

11. SUBMATRICULATION

Outstanding undergraduate students at the university may submatriculate in the M.S.E. 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 B.S.E. and a M.S.E. degree. Undergraduates at the University of Pennsylvania may double-count up to three graduate-level courses taken while enrolled as a submatriculant towards both the undergraduate and the graduate degree. The M.S.E. 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:

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

Applications to the graduate program must be completed on-line by the end of the junior year. In addition, students are required to submit a submatriculation application. These are available in the Office of Graduate Admissions (111 Towne Building) and should be completed after an admission decision letter is mailed by the school.

12. DUAL DEGREE PROGRAMS

Dual Degree in Two Engineering Disciplines

Students may enroll in a dual degree program and receive an M.S.E. 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 Engineering. The dual degree program requires the completion of at least 17 courses and satisfaction of the M.S.E. requirements of each department in which the student wishes to major. This program typically requires four 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 in the Academic Programs Office in 111 Towne Building.

M.B.A./M.S.E. 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 (M.B.A.) and Master of Science in Engineering (M.S.E.). Typically, the program requires 5 semesters of study. To participate in the M.B.A./M.S.E. 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 899 or 999) 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 Graduate Group Chair, must approve summer school courses.

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

14. RECORDS

The official graduate student records are kept in 111 Towne Building; transcripts can be viewed on Penn InTouch at https://sentry.isc.upenn.edu/intouch. Graduate students are encouraged to periodically check the accuracy of their records and to bring any discrepancies to the attention of the Graduate Group Chair.

15. GRADUATE ENVIRONMENT

The spirit and size of the Department of Mechanical Engineering and Applied Mechanics fosters a close interaction between the graduate students and the entire faculty. This enhances the quality of student-faculty communications and enriches the academic environment to benefit both learning and discovery.

Apart from offering advising, seminars and meetings to introduce incoming students to faculty research, and informal meetings with the Department Chair and Graduate Group Chair to solicit student input and exchange information, 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 becomes a member of the Graduate Group of the department, with voting rights, and serves as a communication channel for information between the Graduate Group and students.

Every effort is made to create an environment of scholarship, creativity and learning, which is the very essence of graduate study.

APPENDIX A

Summary of M.S.E. Degree Course Requirements

Math Requirement	2 Courses
MEAM Core Requirement	5 Courses
Electives Requirement	3 Courses
Seminar Requirement *Full time students only	2 Semesters
Total	10 Courses

MATHEMATICS REQUIREMENTS

All M.S.E. students are required to take at least two mathematics courses selected from the following list:

ENM[4] 502	Numerical Methods and Modeling
ENM 503	Introduction to Probability and Statistics
ENM 510	Foundations of Engineering Mathematics I
ENM 511	Foundations of Engineering Mathematics II
ENM 520	Computational Methods for ODE/PDE-Constrained Optimization
ENM 600	Advanced Engineering Mathematics
ENM 601	Special Topics in Engineering Mathematics

Prior approval from the Graduate Group Chair is required if a student would like to take a course other than the ones listed above to satisfy the math requirement.

ELECTIVES

The three graduate level electives should be chosen in consultation with the academic advisor. These electives are typically in other SEAS departments or within MEAM, and courses taken outside of SEAS departments should be relevant to the student's career goals or to the subdiscipline in which the student is interested.

MEAM COURSES

The five required MEAM courses could be chosen from the following lists, which are separated into subdisciplines. Three of the five must be in the student's concentration area.

List of approved courses for students concentrating in Mechanical Systems

[4] ENM - Engineering Mathematics

DESIGN AND MANUFACTURING

Global business trends have created a demand for companies to rapidly develop new products at lower costs. In response 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.

The laboratory facilities include the General Robotics and Active Sensory Perception (GRASP) Laboratory, the Prototyping and Design Lab, the Microfabrication Laboratory, the Center for Human Modeling and Simulation, Laboratory for Research on the Structure of Matter (LRSM), and the Institute for Medicine and Engineering (IME).

(Preapproved Core Requirement Courses)

MEAM 510	Mechatronics
MEAM 511	Visual Thinking
MEAM 512	Industrial Design Basics
MEAM 514	Design for Manufacturability
MEAM 515	Product Design
MEAM 527	Finite Element Analysis
MEAM 540	Optimal Design of Mechanical Systems
MEAM 550 (EE 550)	Design and Modeling of Micro-Electro-Mechanical Systems

(Preapproved Electives Requirement Courses)

CIS 510	Computer-Aided Design
CIS 560	Computer Graphics
ARCH 722	Furniture Design
ESE 524 (OPIM 627)	Operations Technology Management
OPIM 654	Product Design and Development
OPIM 655	Operations, Marketing, and Design Integration
EAS 545/546/547/548	Eng. Entrepreneurship I/ Eng. Entrepreneurship II/High Tech. Ventures/High Tech. Development

List of approved courses for students concentrating in Mechanical Systems

ROBOTICS AND MICRO ELECTROMECHANICAL SYSTEMS (MEMS)

Ongoing effort in mechanical systems focuses on modeling and controlling dynamical systems, robotics, design and manufacturing, and micro electromechanical systems (MEMS). 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, among others, the Departments of Bioengineering, Computer and Information Science, Electrical and Systems Engineering as well as the Wharton School of Business Administration.

The laboratory facilities include the General Robotics and Active Sensory Perception (GRASP) Laboratory, the Manufacturing Technologies Laboratory (MTL), the Microfabrication Laboratory, the Center for Human Modeling and Simulation, Laboratory for Research on the Structure of Matter (LRSM), and the Institute for Medicine and Engineering (IME).

(Preapproved Core Requirement Courses)

MEAM 510	Mechatronics
MEAM 513	Modern Feedback Control Theory
MEAM 520	Robotics and Automation (with a laboratory component)
MEAM 522 (EE 522 / EE 523)	Fundamentals of Sensors, Actuators, & Micro Structures
MEAM 529	RF MEMS
MEAM 535	Advanced Dynamics
MEAM 540	Optimal Design of Mechanical Systems
MEAM 550 (EE 550)	Design and Modeling of Micro-Electro-Mechanical Systems
MEAM 564 (EE 564)	The Principles and Practice of Microfabrication Technology
MEAM 613	Nonlinear Control Theory
MEAM 644	Haptic Interfaces for Virtual Environments and Teleoperation

(Preapproved Electives Requirement Courses)

CIS 510	Computer-Aided Design
CIS 520	Introduction to Artificial Intelligence
CIS 580	Machine Perception
ESE 525	Nanometer Scale Science & Engineering
EAS 545/546/547/548	Eng. Entrepreneurship I/ Eng. Entrepreneurship II/High Tech. Ventures/High Tech. Development

List of approved courses for students concentrating in:

HEAT TRANSFER, FLUID MECHANICS, AND ENERGY SCIENCE AND

ENGINEERING

An educational foundation in the thermo-fluids and energy conversion fields is necessary for work in aerospace engineering; in most manufacturing processes such as thin film deposition, plasma and laser processing, joining and welding, fabrication of polymers and metals, ion-beam and electro-discharge machining, cooling of microelectronic equipment and advanced computer chips; as well as in all energy conversion and power generation processes; and in thermal control and treatment of living organisms. The Penn MEAM M.S.E. program in Thermo-Fluids 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.

(Preapproved Core Requirement Courses)

MEAM 502	Energy Engineering
MEAM 527	Finite Element Analysis
MEAM 533	Advanced Heat and Mass Transfer
MEAM 545	Aerodynamics
MEAM 536	Viscous Fluid Flow
MEAM 561	Thermodynamics I
MEAM 575	Physicochemical Hydrodynamics and Interfacial Phenomena
MEAM 570	Introduction to Transport
MEAM 572	Micro/Nano Energy Transport
MEAM 561	Thermodynamics
MEAM 530	Continuum Mechanics
MEAM 642	Fluid Mechanics I
MEAM 643	Fluid Mechanics II
MEAM 644	Fluid Mechanics III: BioTransport: Fluid Mechanics, Heat and Mass Transfer
MEAM 645	Fluid Mechanics IV
MEAM 646	Computational Mechanics
MEAM 647	Non-Newtonian Fluid Dynamics
MEAM 664	Heat Conduction and Mass Diffusion
MEAM 665	Heat Transfer II - Convection
MEAM 666	Heat Transfer III - Radiation

(Preapproved Electives Requirement Courses)

BE 660	Circulatory System Dynamics
ChE 551	Analysis and Design of Microbial Systems
ChE 502	Nonlinear Methods in Chemical Engineering
ChE 520	Modeling, Simulations, and Optimization of Chemical Processes
ChE 617	Control of Nonlinear Systems
ChE 618	Application of Thermodynamics in Chemical Engineering I
ChE 619	Application of Thermodynamics in Chemical Engineering II
ChE 640	Transport Processes I
ChE 641	Transport Processes II
ChE 702	Surface Science
CPLN 554	Environmental Management and Evaluation
CPLN 719	Environmental and Energy Planning Challenges for Cities
EAS 545/546/547/548	Eng. Entrepreneurship I/ Eng. Entrepreneurship II/High Tech. Ventures/High Tech. Development

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 the biomedical technologies, often require the development and understanding of completely new classes of materials systems. The Penn MEAM M.S.E. in Mechanics of Materials is designed to provide the basic tools in Mechanics and Materials 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.

(Preapproved Core Requirement Courses)

MEAM 519	Introduction to Elasticity
MEAM 554	Mechanics of Materials
MEAM 555	Membranes, Shells & Polymers in Biology
MEAM 530	continuum mechanics
MEAM 537	Nanomech & Nanotribology
MEAM 631	Advanced Elasticity
MEAM 632	Plasticity
MEAM 633	Fracture Mechanics
MEAM 634	Wave Propagation
MEAM 635	Composite Materials

(Preapproved Electives Requirement Courses)

BE 645	Biological Elasticity
BE 647	Biomechanics
MSE 550	Mechanical Behavior of Materials
MSE 650	Micromechanisms of Deformation & Fracture
MSE 660	Atomistic Modeling in Materials Science
EAS 545/546/547/548	Eng. Entrepreneurship I/ Eng. Entrepreneurship II/High Tech. Ventures/High Tech. Development

List of approved courses for students concentrating in:
BIO-MECHANICS

(Preapproved Core Requirement Courses)

MEAM 554	Mechanics of Materials
MEAM 555	Membranes and Polymers in Biology
MEAM 570	Introduction to Transport Phenomena
MEAM 527	Finite Element Analysis
MEAM 663	Entropic Forces in Biomechanics
MEAM 665	Intermediate Transport Phenomena
MEAM 635	Composite Materials
MEAM 642	Fluid Mechanics I

(Preapproved Electives Requirement Courses)

EAS 545/546/547/548	Eng. Entrepreneurship I/ Eng. Entrepreneurship II/High Tech. Ventures/High Tech. Development

Upper level Grad course in the BioSciences

APPENDIX B

Hard Cover Instructions for M.S.E. Theses

Guidelines:

In addition to the unbound copies that must be given to the Office of the Associate Dean for Graduate Education and Research, one hardbound copy of each M.S.E. thesis must be submitted to the Graduate Group Chair and one hardbound copy must be submitted to the student's 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.

M.S.E. 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

M.S.E. Dissertation
Mechanical Engineering and Applied Mechanics
University of Pennsylvania
2008

And on the spine (from top to bottom):

Neuman Design Optimization and Control of a Multi-robot System (etc., as much as space will allow, use ... at end if space is insufficient) MEAM M.S.E. 2008.

APPENDIX C

GRADUATE TRANSFER OF CREDIT PETITION

TO: SEAS Associate Dean for Academic Affairs

FROM: _____ _____
Name of Student PENN ID #:

DEPT: _____

DATE: _____

Include with this petition, course numbers and descriptions from the appropriate bulletin listing and a final transcript. A maximum of **two** courses may be transferred to the Master's program or a maximum of **eight** to the Ph.D. program if approved. Courses counted towards an undergraduate degree will not be considered for graduate credit unless in an approved submatriculation program.

TRANSFER OF CREDIT TO: ☐ Master's program ☐ Ph.D. program

FROM WHICH UNIVERSITY: _____

Please list courses to be transferred and SEAS equivalent if applicable:

	COURSE	SEAS EQUIVALENT	# CUS
1)			
2)			
3)			
4)			
5)			
6)			
7)			
8)			

_____
Adviser's Approval Date

_____
Graduate Group Chairman Date

☐ Approved ☐ Disapproved

_____
Associate Dean for Academic Affairs Date

APPENDIX D

MEAM Graduate Group Members

Paulo E. Arratia, Assistant Professor. Micro- and Nanofluidics, Complex Fluids such as polymeric & biological materials, Transport Phenomena with emphasis on fluid & nonlinear dynamics, Rheology, and Soft-Condensed Matter including granular media.

P. S. Ayyaswamy, Asa Whitney Professor of Dynamical Engineering. Phase change heat and mass transfer processes, bioheat/mass transfer, arc-plasma heat transfer, and thermal aspects in MEMS.

John L. Bassani, Richard H. and S. L. Gabel Professor of Mechanical Engineering and Chair. Plastic deformation of crystals, atomic/continuum property relationships, interface mechanics, fracture mechanics, material stability at large strains, mechanics of living cells.

Haim H. Bau, Professor. Micro and nano fluidics, nanotechnology, fluid and particle motion under the action of electric and magnetic fields, and bifurcation and instability phenomena in and feedback control of flows.

George Biros, Assistant Professor. Computational science and engineering, optimization algorithms, inverse problems, computational fluid mechanics, integral equations, fast multipole methods, parallel and scientific computing.

Robert W. Carpick, Associate Professor. Experimental nanomechanics and nanotribology (friction, adhesion, lubrication, wear). Development, characterization, and applications of materials and devices at the nanoscale. Development and application of advanced scanning probe microscopy tools.

Thomas A.V. Cassel, Professor of Practice, Mechanical Engineering and Applied Mechanics. Engineering Entrepreneurship.

Stuart Churchill, Carl V. S. Patterson Professor Emeritus of Chemical and Biomolecular Engineering. Combustion, rate processes and correlation, the prediction of turbulent flow and convection.

Dennis E. Discher, Professor of Chemical and Biomolecular Engineering. Mechanics and structural assemblies of biomolecules, mechanochemistry of cells, mechanics and statistical mechanics of networks and complex fluids.

David M. Eckmann, Horatio C. Wood Professor of Anesthesiology & Critical Care. Experimental and computational biofluid dynamics, interfacial fluid mechanics, molecular mechanics of cellular activation and biological adhesion to vascular tissue, biomimetic materials and targeted drug delivery

Dawn M. Elliott, Associate Professor of Orthopaedic Surgery and Bioengineering. Orthopaedic biomechanics of the intervertebral disc; anisotropic, nonlinear, and viscoelastic biomechanics; models of disc degeneration; structure-function of the disc.

Howard H. Hu, Associate Professor. Modeling of complex flows with multiphase or polymeric fluids, computational fluid dynamics, hydrodynamic stability.

Daniel E. Koditschek, Alfred Fitler Moore Professor and Chair of Electrical and Systems Engineering. Robotics, computational neuromechanics, dynamical systems theory applied to design of intelligent machines and their control.

Katherine J. Kuchenbecker, Skirkanich Assistant Professor of Innovation in Mechanical Engineering. Design and control of haptic interfaces, virtual reality, teleoperation, and medical robotics.

Vijay Kumar, UPS Foundation Professor Associate Dean. Robotics, multi-vehicle control, dynamical systems, systems biology.

Noam Lior, Professor. Energy conversion, advanced power generation, global warming alleviation, solar energy, combustion, water desalination, destruction of hazardous wastes by photocatalysis and supercritical oxidation, materials processing.

Jennifer R. Lukes, Associate Professor. Nanoscale thermal, fluid, and mass transport; molecular dynamics simulation; laser-based materials characterization; field-directed patterning for nanofabrication; flow measurement in confined geometries; micro- and nanoscale engineering.

Charles J. McMahon, Jr., Professor Emeritus, Materials Science and Engineering. Mechanisms of intergranular embrittlement and fracture in high-strength structural materials, especially as related to environmental effects. Current interests are dynamic embrittlement in nickel and copper-based alloys and in steels.

George J. Pappas, Professor of Electrical and Systems Engineering. Hybrid systems, hierarchical control systems, embedded systems, nonlinear systems, geometric control theory, robotics, unmanned aerial vehicles.

Gianluca Piazza, Assistant Professor of Electrical and Systems Engineering. Micro/NanoElectroMechanical Systems (MEMS/NEMS), Piezoelectric Materials, Wireless Transducers, Sensors and Actuators, Biochemical Detectors, Micro/Nanofabrication Techniques.

Pedro Ponte Castañeda, Professor and Graduate Group Chair. Nonlinear composite and polycrystalline materials, smart materials, microstructure evolution and localization in manufacturing processes, mechanics of polymers, fracture mechanics, nonlinear variational principles in mechanics

Prashant Purohit, Assistant Professor. Rod theories for DNA and biopolymers, Mechanics of sub-cellular organelles, Mechanics at the bio-nano interface, Martensitic phase transitions in solids.

Talid R. Sinno, Associate Professor of Chemical and Biomolecular Engineering. Transport and reaction in electronic materials processing, computational and statistical mechanical modeling

Louis J. Soslowsky, Fairhill Professor of Orthopaedic Surgery and Professor of Bioengineering and Director of Penn Center for Musculoskeletal Disorders. Orthopaedic biomechanics and functional tissue engineering; structure-function studies of tendons and ligaments; models of tendon injury, repair, and healing; shoulder joint mechanics.

Camillo J. Taylor, Associate Professor of Computer and Information Science. Reconstructing and rerendering 3D scenes from 2D images and vision guided robotic systems.

Karl T. Ulrich, CIBC Professor of Operations and Information Management (Wharton School) and Chairperson. Product design, product development, technology development, personal transportation, environmental issues.

Vaclav Vitek, Professor of Materials Science and Engineering. Computer modeling of the structure and properties of grain boundaries, metal-metal and metal-ceramic interfaces, dislocations and other lattice defects.

Beth A. Winkelstein, Associate Professor of Bioengineering and Neurosurgery. Spine biomechanics; modeling & experimental methods in subfailure mechanics; joint mechanics; mechanical modulation of pain and cellular dysfunction; models of ligament & nerve injury.

Mark Yim, Associate Professor, Gabel Family Term Junior Professor of Mechanical Engineering and Undergraduate Curriculum Chair. Modular Self-reconfigurable Robotics, Virtual reality (haptics), meso-scale devices (typically larger than MEMS).

APPENDIX E

Mechanical Engineering and Applied Mechanics
Worksheet for Course Registration

Name: _____

Year Matriculated:_____ Degree program:_____(Ph.D./M.S.E.) Status: _____(Full-time/Part-time)

Concentration Area: _____

Proposed Thesis Topic and/or Title (if applicable):

_____

PROPOSED COURSES OF STUDY FOR (TERM/s) _____ and _____

	Course	Section	CUs	Title	Comments
1	_____	_____	____	_____	_____
2	_____	_____	____	_____	_____
3	_____	_____	____	_____	_____
4	_____	_____	____	_____	_____
5	_____	_____	____	_____	_____

Have you met the appropriate milestones for your program at this point? If not, please discuss with your faculty advisor.

_____

_____

_____

Additional notes (if any):

_____

_____ _____

Student's Signature Date

Required only for first-year Masters and Ph.D. students

"I have met with the student and discussed the course plan for the term(s) indicated above."

_____ _____

Advisor's Signature Date

M.S.E. Degree Requirements

- 10 CUs = 5 MEAM (3 in area of concentration) + 2 ENM/Math + 3 free preapproved electives.
- An optional masters thesis may be counted up to 3 CUs.
- Up to two CUs may be transferred from another institution subject to approval by the Graduate Group.
- Two seminar (MEAM 699) CUs are required of full-time students only.

Ph.D. Degree Requirements

- A total of 20 CUs (including 899/999). MEAM 530, 535, and 570; three ENM classes (choose from: 510, 511, 600, 601, 603) are required.
- Up to eight CUs may be transferred from another institution subject to approval by the Graduate Group.
- Teaching Practicum in three semesters, Thesis Proposal, Departmental Seminar, and Thesis research, defense, and submission are required.
- Six seminar (MEAM 699) CUs are required.

Recommended Time Line for Ph.D. Students

By the End of Semester	Milestones
1	Define an independent study course topic and choose a faculty advisor
2	Submit a paper summarizing the independent study by the last day of finals
2+one month	Make an oral presentation of the independent study paper (Qualifying examination)
2+two months	Submit and obtain approval for a course plan
2	Register for first teaching practicum
3	Choose an area for thesis research
3	Register for second teaching practicum
4	Register for third teaching practicum
6 or 7	Present and obtain approval for a thesis proposal
8 or 9	Present a departmental seminar
TD – 2 months	Submit a dissertation draft to your Advisor
TD - 3 weeks	Submit a revised dissertation draft to your dissertation committee
TD - 3 weeks	Submit abstract to Graduate Administrative Assistant for publicizing thesis presentation
TD	Defend thesis
	Make corrections and modifications to the thesis
GD - 4 weeks	Submit a copy of the thesis to the Graduate Group Chair for approval
GD	Submit final thesis to the Graduate School
GD	Graduate!

TD → thesis-defense date **GD → graduation date**

MEAM 899/999 Section Numbers

Fall & Spring	
022	Arratia
002	Ayyaswamy
003	Bassani
004	Bau
005	Carpick
006	Discher
007	Hu
008	Kumar
023	Kumar/Fiene
009	Lior
010	Biros
011	Ponte Castañeda
012	Lukes
013	Kuchenbecker
014	Soslowsky
015	Vitek
016	Taylor
017	Yim
018	Elliott
019	Piazza
001	Purohit
020	Winkelstein
023	Kumar & Fiene

Summer 1	
939	Arratia
911	Ayyaswamy
912	Bassani
913	Bau
930	Biros
914	Carpick
915	Discher
935	Elliott
916	Hu
910	Kuchenbecker
917	Kumar
918	Lior
919	Lukes
937	Piazza
931	Ponte Castañeda
910	Purohit
932	Soslowsky
936	Tylor
933	Vitek
936	Yim
938	Winkelstein

Summer 2	
949	Arratia
921	Ayyaswamy
922	Bassani
923	Bau
940	Biros
924	Carpick
925	Discher
945	Elliott
926	Hu
920	Kuchenbecker
927	Kumar
928	Lior
929	Lukes
947	Piazza
941	Ponte Castañeda
920	Purohit
942	Soslowsky
944	Taylor
943	Vitek
946	Yim
948	Winkelstein

*Students are required to follow the policies and procedures outlined in the guidelines for the year they matriculated. Last Updated 8/08