



UNDERGRADUATE STUDENT MANUAL

**Department of Mechanical Engineering
and Applied Mechanics**

University of Pennsylvania

September 2010

www.me.upenn.edu

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WHAT IS MECHANICAL ENGINEERING AND APPLIED MECHANICS?

What is Mechanical Engineering and Applied Mechanics?

Mechanical engineering and applied mechanics is the study of energy conversion, forces, deformations, and motions of solid bodies and fluids, heat generation and transport, and applications to analysis, design, and manufacture of mechanisms, machines, and their components.

The Department

The Department of Mechanical Engineering and Applied Mechanics (MEAM) was the second engineering curriculum established in the University of Pennsylvania (c. 1872), and its many alumni are noted for their distinguished careers and contributions in engineering, management, science, and education.

Careers in Mechanical Engineering and Applied Mechanics

The Mechanical Engineering and Applied Mechanics (MEAM) curriculum at Penn offers its students a broad based education that will allow them to adapt to developments in technology in a rapidly changing society. At the same time, the curriculum offers the flexibility to specialize in one or more areas in mechanical engineering such as computer-aided-design and manufacturing (CAD/CAM), energy engineering, mechanical design, fluid mechanics, or structure mechanics and cross-disciplinary areas as robotics, biomechanics, micro-electromechanical systems (MEMS), or mechanics of materials. Our students are encouraged to do research during their course of study and are provided every opportunity to master critical skills enabling success in their future careers.

The career opportunities available to our graduates are perhaps the broadest among all fields of engineering. A wide variety of industries recruit mechanical engineers, including aerospace, automotive, electronics and computers, chemical, and biomedical. Positions range from research and development to design and manufacturing to field engineering and marketing. Some recent graduates have taken positions with consulting and financial institutions, while others have gone on to graduate studies in engineering, business, law, and medicine.

ADVISING AND DEGREE INFORMATION

Undergraduate Advisor

All students are assigned a faculty member as an advisor. This faculty member will approve administrative forms such as courses and petitions. He or she will also serve as a resource for advice on academic, career, or other issues that may arise. Students are assigned advisors as freshmen. Every effort will be made to maintain continuity year-to-year, although there are circumstances where advisors need to be changed. Students may change to any advisor that will accept them.

Mailbox

Every student in the School of Engineering and Applied Science has a personal mailbox. Undergraduate mailboxes (mail “folders”) for the Department of Mechanical Engineering are located on the second floor of the Towne Building in room 279. Students should get into the habit of checking his/her mailfolder on a regular basis.

Submatriculation

Undergraduate students may begin an engineering graduate program while still completing their undergraduate program. Application is normally made before the end of the student's junior year. The submatriculant may take up to three graduate courses to fulfill both undergraduate and graduate degree requirements while registered as an undergraduate student. To apply for submatriculation, submit an application via Penn's online application system. A minimum GPA of 3.0 is required in order to apply for submatriculation.

Minor in Mechanical Engineering and Applied Mechanics

A minor in Mechanical Engineering and Applied Mechanics (MEAM) requires the completion of at least six approved course units with a grade of C or better. Courses taken on a pass/fail basis do not count toward the MEAM minor. The approved courses include all courses with the prefix MEAM and ENM 427. At most two course units may be at the 100 level (i.e., MEAM 1XX).

STUDENT ORGANIZATIONS

Student engineering societies traditionally are a strong force in shaping professional attitudes and providing information about the profession and job directions. It also provides opportunities for meeting practicing engineers and for socializing with people of similar professional interests.



ASME Student Chapter

www.seas.upenn.edu/~asme/

The American Society of Mechanical Engineers (ASME) functions as a student technical and professional society. Students elect their own officers and conduct a variety of programs of academic, professional and social interest to them.

President: Nihar Naik, niharn@wharton

Faculty Advisor: Prof. Mark Yim, yim@grasp.cis

Formula SAE Car

www.seas.upenn.edu/~fsae/

Students design, fabricate, and compete with small formula-style race cars. The vehicles are judged in three different categories: static inspection and engineering design, solo performance trials, and high-performance track endurance.

Captain: Ryan-Jinhan Kumbang, ryak@seas

Faculty Advisor: Prof. Robert Jeffcoat, rlj@seas

Penn Electric Racing

www.seas.upenn.edu/~electric/

Penn Electric Racing is a student-run project with the purpose of designing, building, and racing alternative energy vehicles. Students are engaged in vehicle design and construction, as well as management, fund-raising and public relations. The team is also involved in educational outreach to the local community.

Team Leader: William Price, wprice@seas

Faculty Advisor: Prof. Robert Jeffcoat, rlj@seas

Pi Tau Sigma

www.pitausigma.net/

Pi Tau Sigma is a Mechanical Engineering Honor Society, instituted in order to establish a closer bond of fellowship among its members which will result in mutual benefit to those in the profession of mechanical engineering. Pi Tau Sigma's core values are: Integrity, Service, and Leadership.



SAE Student Chapter

www.seas.upenn.edu/~sae/

Penn's chapter of the Society of Automotive Engineers is just a small part of the international SAE presence. Over 84,000 engineers, business executives, educators, and students from more than 97 countries form a network of membership who share information and exchange ideas for advancing the engineering of mobility systems.



CURRICULUM IN MECHANICAL ENGINEERING AND APPLIED MECHANICS

Mechanical engineering students are expected to formulate a degree program well-grounded in the fundamentals of mechanical engineering while having the breadth that is necessary in today's technology-intensive workplace. The curriculum contains sufficient flexibility so that the student can pursue a number of elective options in depth, either in traditional mechanical engineering subjects or in one or more multidisciplinary engineering programs at Penn. Flexibility in the curriculum, primarily in the junior and senior years, enables the student to pursue an elective program in fields such as aeronautics, robotics, design and manufacturing, mechatronics, business administration, advanced mathematics, control systems, and mechanics of materials.

To earn a BSE in MEAM, a student must complete at least 40 course units distributed among various categories as listed below:

| | |
|-------|--|
| | 5 credit units = Math |
| | 5 credit units = Natural Science |
| | 10 credit units = Core MEAM courses |
| | 10 credit units = Professional Electives |
| | 7 credit units = General Electives |
| + | 3 credit units = Free Electives |
| <hr/> | |
| | 40 credit units = Total |

COURSE PLANNING GUIDE

On the following page, you will find the Course Planning Guide (CPG). The CPG will indicate which of the above courses are required and which are recommended. It will also include websites for further information, such as the writing requirement.

The CPG can also be found:

- MEAM website: <http://www.me.upenn.edu/current-students/undergraduates/degree-requirements.php>
- Penn InTouch: https://medley.isc-seo.upenn.edu/penn_portal/intouch/splash.html

MEAM COURSE PLANNING GUIDE

Math (5 CU)

www.seas.upenn.edu/undergraduate/handbook/courses/math-courses.php

- MATH 104 Calculus I (Section 007 is recommended)
- MATH 114 Calculus II
- MATH 240 Calculus III
- MATH 241 Calculus IV or ENM 251
- _____¹

1. Recom: EAS 205 Applications of Scientific Comp

Natural Science (5 CU)

www.seas.upenn.edu/undergraduate/handbook/courses/nat-science-courses.php

- MEAM 110 Intro to Mechanics (or PHYS 093)
- MEAM 147 Intro to Mechanics Lab (or PHYS 050)
- PHYS 151 Prin. of Physics II (or PHYS 094+051)
- CHEM 101 Chemistry I (Section 4, 5 or CHEM 091)
- CHEM 053 Chemistry Lab I
- _____²

2. Recom: BIOL 101 Intro. To Biology
 BIOL 121 Intro Bio-Molec Bio Life
 PHYS 280 Biological Physics

Core MEAM (10 CU)

- MEAM 203 Thermodynamics I
- MEAM 210 Statics & Str. of Materials
- MEAM 211 Eng Mechanics: Dynamics
- MEAM 247 MEAM Lab I – Fall
- MEAM 247 MEAM Lab I – Spring
- MEAM 302 Fluid Mechanics
- MEAM 321 Vibrations of Mech Sys
- MEAM 333 Heat & Mass Transfer
- MEAM 347 ME Design Lab
- MEAM 348 ME Design Lab
- MEAM 354 Mechanics of Solids

Note:

Bold courses are required MEAM courses.

Professional Electives (10 CU)³

- MEAM 445 Design Project I
- MEAM 446 Design Project II
- EAS 105 Intro to Scientific Computing⁴
- MEAM Upper level _____⁵
- MEAM Upper level _____⁵
- MEAM Upper level _____⁵
- Professional Elective _____⁶
- Professional Elective _____⁶
- Professional Elective _____^{6,7}
- Professional Elective _____^{6,7}

3. Max of three 100-level courses.
4. CIS 110, CIS 120 or ESE 112 are also acceptable.
5. MEAM 402, 410, 454, 455, 513, 514, 520, 545
 ENM 427, others by petition.
6. Math, Natural Science or Engineering categories.
7. Advanced dual degree requirements with approval.

General Electives (7 CU)

www.seas.upenn.edu/undergraduate/handbook/courses/ssh-breadth.php

www.seas.upenn.edu/undergraduate/handbook/courses/tech-bus-courses.php

- SS _____ H _____
- SS _____ H _____
- SS or H _____ SS, H or TBS _____
- SS, H or TBS _____

Two general electives (above) must be taken in the same department. The second of the two is known as:

Depth _____

One general elective (above) must fulfill the:

Writing Requirement _____

www.seas.upenn.edu/undergraduate/handbook/courses/writing-requirement.php

Free Electives (3 CU)

www.seas.upenn.edu/undergraduate/handbook/courses/free-elective.php

- _____
- _____
- _____

MEAM B.S.E. SAMPLE FOUR-YEAR COURSE PLAN

Many courses have prerequisites, and therefore, the sequence in which courses are taken may be important. The following sample course plan shows one sequence which satisfies the prerequisites for the specified courses. However, each student must develop a complete course plan in consultation with his or her academic advisor.

Freshman Year

| CU's | | | CU's | | |
|--|-------------------------------------|--------------------------|--------|---|--------------------------------|
| FALL | | | SPRING | | |
| 1.5 | MEAM 110/147 | Intro to Mechanics & Lab | 1.5 | PHYS 151 | Principles of Physics II & Lab |
| 1 | MATH 104-007 | Calculus I | 1 | MATH 114 | Calculus II |
| 1.5 | CHEM 101/053 | Intro to Chemistry & Lab | 1 | Professional elective (i.e. MEAM 101 or MEAM 150) | |
| 1 | Elective: Social Science/Humanities | | 1 | Writing Requirement | |
| Students with AP credit may take EAS 105 or MEAM 101 in lieu of MEAM110 or MATH104 | | | 1 | Natural Science elective | |

Sophomore Year

| CU's | | | CU's | | |
|------|------------------------------------|---------------------------------------|--------|------------------------------------|---------------------------------------|
| FALL | | | SPRING | | |
| 1 | EAS 105 | Intro to Scien. Comp. | 1 | MEAM 203 | Thermodynamics I |
| 1 | MEAM 210 | Statics and Strength of Materials | 1 | MEAM 211 | Engineering Mechanics: Dynamics |
| .5 | MEAM 247 | Mechanical Engineering Laboratory I-A | .5 | MEAM 247 | Mechanical Engineering Laboratory I-B |
| 1 | MATH 240 | Calculus III | 1 | ENM 251 or | Analytical Methods for Eng |
| 1 | Professional elective | | 1 | MATH 241 | Calculus IV |
| 1 | Social Science/Humanities elective | | 1 | Social Science/Humanities elective | |

Junior Year

| CU's | | | CU's | | |
|------|------------------------------------|-----------------------------------|--------|---|-----------------------------------|
| FALL | | | SPRING | | |
| 1 | MEAM 302 | Fluid Mechanics | 1 | MEAM 333 | Heat and Mass Transfer |
| 1 | MEAM 321 | Vibrations | 1 | MEAM 354 | Mechanics of Solids |
| 1 | MEAM 347 | Mechanical Engineering Design Lab | 1 | MEAM 348 | Mechanical Engineering Design Lab |
| 1 | Social Science/Humanities elective | | 1 | Upper-level MEAM course | |
| 1 | Free elective | | 1 | Math elective i.e. Linear algebra, statistics, ENM427 | |

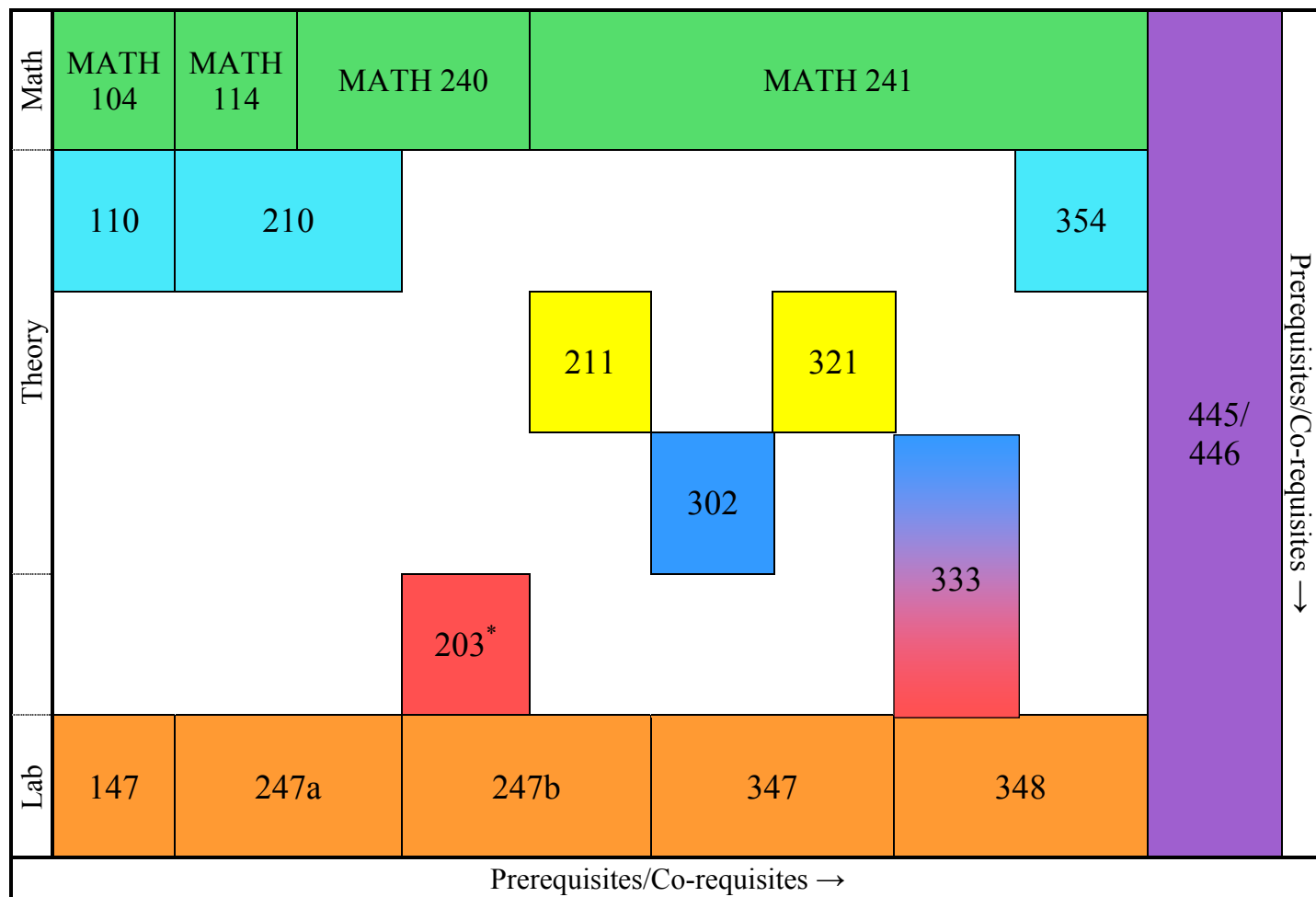
Senior Year

| CU's | | | CU's | | |
|------|---|--|--------|---|--|
| FALL | | | SPRING | | |
| 1 | MEAM 445 | Mechanical Engineering Design Projects | 1 | MEAM 446 | Mechanical Engineering Design Projects |
| 1 | Upper-level MEAM course | | 1 | Upper-level MEAM course | |
| 1 | Professional elective | | 1 | Professional elective | |
| 1 | Social Science/Humanities /TBS elective | | 1 | Social Science/Humanities /TBS elective | |
| 1 | Free elective | | 1 | Free elective | |

| |
|--|
| Note: Bold courses are required MEAM courses. |
|--|

MEAM CONCEPT FLOWCHART

This chart shows the connections between the core MEAM courses.



Top to Bottom: Top courses are prerequisites or co-requisites for the courses underneath. Concepts from the courses on top are used in courses underneath.

Left to Right: Courses on the left are prerequisites or co-requisites for courses to their right. Concepts from the courses on the left are used in courses on the right.

*Note: MEAM 203 has no prerequisites.

MEAM ELECTIVE SCHEDULE

<http://www.me.upenn.edu/current-students/undergraduates/elective-schedule.php>

Fall 2010 Electives

| | |
|-----------------------------|--|
| MEAM 101 | Intro to Mechanical Design |
| MEAM 150 | Fundamentals of Mechanical Prototyping |
| MEAM 245 | Intro to Flight |
| MEAM 250 | Energy Systems, Resources and Technology |
| MEAM 402/502 | Energy Engineering |
| MEAM 405/505 | Mech Prop Nano/ Macro |
| MEAM 410/510 | Design of Mechatronic Systems |
| ENM 427/MEAM 527 | Finite Elements and Applications |
| MEAM 511, IPD 511 | Creative Thinking and Design |
| MEAM 515, IPD 515, OPIM 415 | Product Design |
| MEAM 529 | RF MEMS |
| MEAM 530 | Continuum Mechanics |
| MEAM 535 | Advanced Dynamics |
| MEAM 555 | Nanoscale Systems Biology |
| MEAM 564 | Principles of Microfab Tech |
| MEAM 570 | Transport Processes |
| MEAM 575 | Micro and Nano Fluidics |
| EAS 105 | Intro to Scientific Computing |
| EAS 401/501 | Energy and its Impacts |
| EAS 545 | Engineering Entrepreneurship I |
| EAS 546 | Engineering Entrepreneurship II |
| ENM 510 | Fundamentals of Engineering Math I |
| IPD 527 | Industrial Design I |

Tentative Spring 2011 Electives

| | |
|-----------------------------|---|
| MEAM 101 | Intro to Mechanical Design |
| MEAM 150 | Fundamentals of Mechanical Prototyping |
| MEAM 250 | Energy Systems, Resources and Technology |
| MEAM 504 | Tribology |
| MEAM 513 | Modern Feedback Control Theory |
| MEAM 514, IPD 514 | Design for Manufacturability |
| MEAM 515, IPD 515, OPIM 415 | Product Design |
| MEAM 520 | Robotics |
| MEAM 537 | Nanomechanics and Nanotribology |
| MEAM 545 | Aerodynamics |
| EAS 402/502 | Renewable Energy and Its Impacts |
| EAS 449, IPD 549 | Product Development/Entrepreneurial Venture |
| EAS 545 | Engineering Entrepreneurship I |
| EAS 546 | Engineering Entrepreneurship II |
| ENM 511 | Foundations of Engineering Math II |
| ENM 540 | Topics in Computation and Engineering |
| IPD 501 | Integrated Computer-Aided Design |
| IPD 509 | Needfinding |

RECOMMENDED ELECTIVES outside of MEAM

| | |
|--------------------|--|
| BIOL 101 | Intro to Biology |
| BIOL 121 | Introduction to Biology - The Molecular Biology of Life |
| BE 450 | Hemodynamics |
| ESE 215 | Electrical Circuits and Systems |
| ESE 301 | Engineering Probability |
| ESE 460 | The Principles and Practice of Microfabrication Technology |
| ESE 522 | Manufacturing Operations Management |
| MSE 220 | Engineering Materials |
| PHYS 280, BCHE 280 | Biological Physics |

**AREAS OF SPECIALIZATION IN
MECHANICAL ENGINEERING AND APPLIED MECHANICS**

A student interested in pursuing certain engineering disciplines in depth should consider choosing his or her electives accordingly. Students are encouraged to take courses and specialize in one or two areas.

We list possible areas of specialization below:

Energy Engineering

| | |
|--------------|----------------------------------|
| MEAM 338 | Thermodynamics II |
| MEAM 402/502 | Energy Engineering |
| MEAM 570 | Transport |
| MEAM 572 | Micro/Nanoscale Energy Transport |
| EAS 401/501 | Energy and Its Impacts |
| EAS 402/502 | Renewable Energy and Its Impacts |

Fluid Mechanics and Aerodynamics

| | |
|-----------------------|---------------------------------|
| MEAM 545 | Aerodynamics |
| MEAM 513, ESE 406/505 | Modern Feedback Control Theory |
| MEAM 530 | Continuum Mechanics |
| MEAM 570 | Transport |
| ENM 427/MEAM 527 | Finite Element and Applications |

Manufacturing

| | |
|-----------------------------|---|
| MEAM 101 | Introduction to Computer Aided Design and Manufacturing |
| MEAM 150 | Fundamentals of Mechanical Prototyping |
| MEAM 410/510 | Design of Mechatronic Systems |
| MEAM 454/554 | Mechanics of Materials |
| MEAM 515, IPD 515, OPIM 415 | Product Design |
| MEAM 520 | Robotics |
| MEAM 564 | Principles of Microfabrication Technology |
| ENM 427/MEAM 527 | Finite Element and Applications |
| ESE 215 | Electrical Circuits and Systems |
| ESE 522 | Process Mgmt in Manufacturing |

Mechatronics

| | |
|--------------|---|
| MEAM 410/510 | Design of Mechatronic Systems |
| MEAM 520 | Robotics |
| MEAM 564 | Principles of Microfabrication Technology |
| CIS 120 | Introduction to Programming |
| ESE 215 | Electrical Circuits and Systems |
| ESE 522 | Process Mgmt in Manufacturing |

Product Design and Innovation

| | |
|-----------------------------|---|
| MEAM 101 | Introduction to Computer Aided Design and Manufacturing |
| MEAM 215 | Elements of Mechanical Engineering Design |
| MEAM 410/510 | Design of Mechatronic Systems |
| MEAM 511, IPD 511 | Creative Thinking and Design |
| MEAM 514, IPD 514 | Design for Manufacturability |
| MEAM 515, IPD 515, OPIM 415 | Product Design |
| EAS 545 | Engineering Entrepreneurship I |
| EAS 546 | Engineering Entrepreneurship II |
| ESE 400/540 | Engineering Economics |

Structural Mechanics & Mechanics of Materials

| | |
|------------------|---------------------------------|
| MEAM 454/554 | Mechanics of Materials |
| MEAM 519/MSE 550 | Introduction to Elasticity |
| MEAM 530 | Continuum Mechanics |
| ENM 427/MEAM 527 | Finite Element and Applications |
| MSE 220/BE 220 | Structural Biomaterials |

Note:

- Courses may not be offered every year.
- Students may consider designing an independent study course, MEAM 099, with a MEAM faculty advisor in any area or across two or more areas.

COURSE DESCRIPTIONS

099. Undergraduate Research and/or Independent Study. Open to all students. A maximum of 2 cu. of MEAM 099 may be applied toward the B.A.S. or B.S.E. degree requirements.

An opportunity for the student to become closely associated with a professor in (1) a research effort to develop research skills and technique and/or (2) to develop a program of independent in-depth study in a subject area in which the professor and student have a common interest. The challenge of the task undertaken must be consistent with the student's academic level. To register for this course, the student and professor jointly submit a detailed proposal.

101. Introduction to Mechanical Design.

This hands-on, project-based course covers the fundamentals of the modern mechanical design process, from needfinding and brainstorming to the basics of computerized manufacturing and rapid prototyping. Topics include: product definition (needfinding, observation, sketching, and brainstorming); computer-aided design (part creation, assemblies, and animation using SolidWorks); fundamental engineering design practices (material selection, dimensioning, tolerances, etc.); basic computer simulation and analysis; and rapid prototyping (laser cutter, 3-D fused-deposition modeling, and an introduction to computer-controlled machining).

110. Introduction to Mechanics. Co-requisite: Math 104.

This lecture course and a companion laboratory course (MEAM 147) build upon the concepts of Newtonian (classical) mechanics and their application to engineered systems. This course introduces students to mechanical principles that are the foundation of upper-level engineering courses including MEAM 210 and 211. The three major parts of this course are: I. Vector Mechanics; II. Statics and Structures; and III. Kinematics and Dynamics. Topics include: vector analysis, statics of rigid bodies, introduction to deformable bodies, friction, kinematics of motion, work and energy, and dynamics of particles. Case studies will be introduced, and the role of Newtonian mechanics in emerging applications including bio- and nano- technologies will be discussed.

147. Introduction to Mechanics Lab. Co-requisite: MEAM 110 or credit for AP Physics C, Mechanics.

This half-credit laboratory class is a companion to the Introduction to Mechanics lecture course (MEAM 110). It investigates the concepts of Newtonian (classical) mechanics through weekly hands-on experiments, emphasizing connections between theoretical principles and practical applications in engineering. In addition to furthering their understanding about the workings of the physical world, students will improve their skills at conducting experiments, obtaining reliable data, presenting numerical results, and extracting meaningful information from such numbers.

150. Fundamentals of Mechanical Prototyping.

Constructing functional prototypes is an intrinsic part of the mechanical design process. This hands-on course covers the fundamentals of layout, measurement, part generation, milling, turning, and computer-controlled machining. By immersion in the department's manufacturing environment, students will gain an intuitive understanding of the techniques and skills necessary to successfully prototype a wide variety of mechanical systems. Enrollment is limited.

203. Thermodynamics I.

Thermodynamics is the study of the fundamental concepts underlying the conversion of energy in such mechanical systems as internal and external combustion engines (including automobile and aircraft engines), compressors, pumps, refrigerators, and turbines. This course is intended for students in mechanical engineering, chemical engineering, materials science, physics and other fields. The topics include: Basic definitions, microscopic and macroscopic points of view; properties of pure substances and reversibility and irreversibility, the thermodynamic temperature scale, entropy, availability, second law analysis, power and refrigeration cycles and their engineering applications.

210. Statics and Strength of Materials. Prerequisite(s): Physics 150 or MEAM 110/147. Corequisite(s): Math 240 and MEAM 247 are strongly recommended.

This course is intended for students in mechanical engineering, systems-civil, materials science and other fields. It continues the treatment of the statics of rigid bodies begun in Physics 150 and MEAM 110 and leads to the treatment of deformable bodies and their response to loads. The concepts of stress, strain, and linearly elastic response are introduced and they are applied to the behavior of rods, beams, shafts and pressure vessels. Safety factors and the onset of mechanical failure are discussed. The course incorporates the use of computers to solve problems, and includes a written library research assignment and a team design project.

211. Engineering Mechanics: Dynamics. Prerequisite(s): MEAM 210 and MATH 240 concurrently.

This course introduces the basic concepts in kinematics and dynamics that are necessary to understand, analyze and design mechanisms and machines. These concepts are also fundamental to the modeling and analysis of human movement, biomechanics, animation of synthetic human models and robotics. The topics covered include: Particle dynamics using energy and momentum methods of analysis; Dynamics of systems of particles; Impact; Systems of variable mass; Kinematics and dynamics of rigid bodies in plane motion; Computer-aided dynamic simulation and animation.

215. Elements of Mechanical Engineering Design. Prerequisite(s): MEAM 210, MSE 220, or equivalent; MATH 240. Corequisite: MEAM 101 helpful but not required.

This course introduces the broad field of mechanical design, in which engineering science and inventive thinking are combined to solve real-world problems. Many of the tools, techniques, materials, and devices required for practical applications are covered, with emphasis on how to intelligently select and employ them. Topics include modern design methods (simulation, graphics, ergonomics, etc), manufacturing processes (machining, casting, automation, etc), and physical components (bearings, gears, pumps, motors, etc). Students receive a comprehensive technological grounding which, in conjunction with theoretical and specialized knowledge, will empower them to produce creative and practicable new designs.

245. Introduction to Flight. Prerequisite(s): PHYS 150 or MEAM 110/147. Corequisite(s): MATH 240. Basic concepts: pressure, density, velocity, forces. The standard atmosphere. Introduction to low speed aerodynamics. Airfoils, wings, and other aerodynamic shapes. Aircraft performance. Aircraft stability and control. Aircraft propulsion.

247. Mechanical Engineering Laboratory I. Prerequisite(s): Sophomore standing in engineering.

Corequisite(s): MEAM 210 (fall), and 203 and 211 (spring), are strongly recommended.

This is a sophomore level laboratory course that students will complete over the fall and spring semesters. The course teaches the principles of experimentation and measurement systems as well as design. The fall semester follows closely with MEAM 210, doing experiments to explore the principles taught in statics and strength of materials. The spring semester follows closely with MEAM 203 and MEAM 211 with project based design projects in thermodynamics and dynamics.

250. Energy Systems, Resources and Technology. Prerequisite(s): Sophomore standing in Engineering. Freshman Chemistry, Freshman Physics or Mechanics.

The course will present a comprehensive overview of the global demand for energy, and the resource availability and technology used in its current and future supply. Through a personal energy audit, students will be made aware of the extensive role that energy plays in modern life, both directly, through electricity and transportation fuel, and indirectly in the manufacturing of goods they use. The course will cover how that energy is supplied, the anticipated global growth in energy demand, the resource availability and the role of science and technology in meeting that demand in a world concerned about climate change. The roles of conservation, improved efficiency and renewable energy in meeting future demand in a sustainable, environmentally benign way will be covered.

ENM 251. Analytical Methods for Engineering. Prerequisite(s): MATH 240 or equivalent along with sophomore standing in SEAS, or permission of instructor(s).

This course introduces students to physical models and mathematical methods that are widely encountered in various branches of engineering. Illustrative examples are used to motivate mathematical topics including ordinary and partial differential equations, Fourier analysis, eigenvalue problems, and stability analysis. Analytical techniques that yield exact solutions to problems are developed when possible, but in many cases, numerical calculations are employed using programs such as Matlab and Maple. Students will learn the importance of mathematics in engineering.

302. Fluid Mechanics. Prerequisite(s): MATH 241 and PHYS 150 or MEAM 110/147.

Physical properties; fluid statics; Bernoulli equation; fluid kinematics; conservation laws and finite control-volume analysis; conservation laws and differential analysis; inviscid flow; The Navier-Stokes equation and some exact solutions; similitude, dimensional analysis, and modeling; flow in pipes and channels; boundary layer theory; lift and drag.

310. Design of Thermal/Fluid Systems. Prerequisite(s): MEAM 203, 302, MATH 241. Corequisite(s): MEAM 333.

The objective of the course is to teach the principles of design, with emphasis on components and systems involving the flow of fluids, heat and mass transfer, air conditioning and refrigeration, energy conversion, power generation, and propulsion. The topics covered include introduction to engineering design, economics, modeling, creativity, thermal/fluid equipment and components, reliability, liability, safety, optimization, and materialization of the design as a market product. At least one team design, construction, and testing project is included.

321. Vibrations of Mechanical Systems. Prerequisite(s): MATH 241 and MEAM 211.

This course teaches the fundamental concepts underlying the dynamics of vibrations for single-degree of freedom, multi-degree and infinite-degree of freedom mechanical systems. The course will focus on Newton's Force Methods, Virtual-Work Methods, and Lagrange's Variation Methods for analyzing problems in vibrations. Students will learn how to analyze transient, steady state and forced motion of single and multi-degree of freedom linear and non-linear systems. The course teaches analytical solution techniques for linear systems and practical numerical and simulation methods for analysis and design of nonlinear systems.

333. Heat and Mass Transfer. Prerequisite(s): MATH 241 and MEAM 302.

This course covers fundamentals of heat and mass transfer and applications to practical problems in energy conversion and conservation. Emphasis will be on developing a physical and analytical understanding of conductive, convective, and radiative heat transfer, as well as design of heat exchangers and heat transfer with phase change. Topics covered will include: types of heat transfer processes, their relative importance, and the interactions between them, solutions of steady state and transient state conduction, emission and absorption of radiation by real surfaces and radiative transfer between surfaces, heat transfer by forced and natural convection owing to flow around bodies and through ducts, analytical solutions for some sample cases and applications of correlations for engineering problems. Students will develop an ability to apply governing principles and physical intuition to solve problems.

338. Thermodynamics II. Prerequisite(s): MEAM 203 or CBE 231.

To introduce students to advanced classical equilibrium thermodynamics based on Callen's postulatory approach, to exergy (Second-Law) analysis, and to fundamentals of statistical and nonequilibrium thermodynamics. Applications to be discussed include advanced power and aerospace propulsion cycles, fuel cells, combustion, diffusion, transport in membranes, materials properties, superconductivity, elasticity, and biological processes.

347. Mechanical Engineering Design Laboratory. Prerequisite(s): Junior standing in engineering.

This is a junior level laboratory course. The course teaches the principles of design and measurement systems including basic electromechanical systems. It follows MEAM 302 and MEAM 321 including experiments in fluid mechanics, and vibration in the design of mechanical systems.

348. Mechanical Engineering Design Laboratory. Prerequisite(s): Junior standing in engineering.

This course is a junior lab which follows MEAM 333 Heat Transfer and MEAM 354 Mechanics of Materials with design projects based on those topics. In the broader context of design/independent skill development, this course also introduces open ended topics, wider design options, and introduces project planning and management.

354. Mechanics of Solids. Prerequisite(s): MEAM 210 or equivalent, BE 200, or permission of instructor.

This course builds on the fundamentals of solid mechanics taught in MEAM 210 and addresses more advanced problems in strength of materials. The students will be exposed to a wide array of applications from traditional engineering disciplines as well as emerging areas such as biotechnology and nanotechnology. The methods of analysis developed in this course will form the cornerstone of machine design and also more advanced topics in the mechanics of materials.

402. (MEAM 502) Energy Engineering. Prerequisite(s): MEAM 203 (Thermodynamics), or equivalent and MEAM 333 or equivalent (Heat Transfer, that could be taken concurrently with MEAM 402).

Quantitative introduction to the broad area of energy engineering, from basic principles to applications. The focus is on the science and engineering, and includes environmental impact and some economics considerations. A review of energy consumption, use, and resources; sustainability, methods of energy and exergy (second law) analysis; power cycles, combined cycles, and co-generation; batteries and fuel cells; nuclear energy and wastes; fusion power; solar energy; power generation in space.

405. (MEAM 505, MSE 405, MSE 505) Mechanical Properties of Macro/Nanoscale Materials.

The application of continuum and microstructural concepts to consideration of the mechanics and mechanisms of flow and fracture in metals, polymers and ceramics. The course includes a review of tensors and elasticity with special emphasis on the effects of symmetry on tensor properties. Then deformation, fracture and degradation (fatigue and wear) are treated, including mapping strategies for understanding the ranges of material properties.

410. (MEAM 510) Design of Mechatronic Systems II. Prerequisite(s): Junior or senior standing in mechanical engineering and a first course in programming.

In many modern systems, mechanical elements are tightly coupled with electronic components and embedded computers. Mechatronics is the study of how these domains are interconnected, and this hands-on, project-based course provides an integrated introduction to the fundamental components within each of the three domains, including: mechanical elements (prototyping, materials, actuators and sensors, transmissions, and fundamental kinematics), electronics (basic circuits, filters, op amps, discrete logic, and interfacing with mechanical elements), and computing (interfacing with the analog world, microprocessor technology, basic control theory, and programming).

ENM 427. (MEAM 527) Finite Elements and Applications. Prerequisite(s): MATH 241 and PHYS 151.

The objective of this course is to equip students with the background needed to carry out finite elements-based simulations of various engineering problems. The first part of the course will outline the theory of finite elements. The second part of the course will address the solution of classical equations of mathematical physics such as Laplace, Poisson, Helmholtz, the wave and the Heat equations. The third part of the course will consist of case studies taken from various areas of engineering and the sciences on topics that require or can benefit from finite element modeling. The students will gain hand-on experience with the multi-physics, finite element package FemLab.

445. Mechanical Engineering Design Projects. Prerequisite(s): Senior standing.

This is a capstone design projects course in mechanical engineering and is required of all mechanical engineering students. Students will be involved in selected group or individual projects emphasizing design, development, and experimentation, under the supervision of a MEAM faculty advisor. Projects are sponsored either by industry or by Penn professors. Alternately, students may propose their own projects. Each project is approved by the instructor and the faculty advisor. The work is spread out over MEAM 445 and MEAM 446. In addition to being involved in the design project, MEAM 445 covers project planning, patent and library searches, professional education, ethics, writing skills, communication, and technical presentations.

446. Mechanical Engineering Design Projects.

This is the second course in the two course sequence involving the capstone design project. See MEAM 445 for course description.

454. (MEAM 554) Mechanics of Materials. Prerequisite(s): MEAM 210, MATH 240, 241.

This course is an upper level course that discusses the behavior of materials, the selection of materials in mechanical components, and the mechanics of deformable bodies. It is intended for students in material science, mechanical engineering, and civil engineering. The topics covered include Rods and Trusses. Stress. Principal Stresses. Strain. Compatibility. Elastic Stress-Strain Relations. Strain Energy. Plane Strain. Plane Stress. Bending of Beams. Torsion. Rotating Disks. Castigliano's Theorem. Dummy Loads. Principle of Virtual Work. The Rayleigh-Ritz Methods. Introduction to the Finite Element Method. Non-Linear Material Behavior. Yielding. Failure.

455. (BE 455, MEAM 544) Continuum Biomechanics.

Continuum mechanics with applications to biological systems. Fundamental engineering conservation laws are introduced and illustrated using biological and non-biological examples. Kinematics of deformation, stress, and conservation of mass, momentum, and energy. Constitutive equations for fluids, solids, and intermediate types of media are described and applied to selected biological examples. Class work is complemented by hands-on experimental and computational laboratory experiences.

502. (MEAM 402) Energy Engineering. Prerequisite(s): MEAM 203 (Thermodynamics), or equivalent and MEAM 333 or equivalent (Heat Transfer, that could be taken concurrently with MEAM 402).

Quantitative introduction to the broad area of energy engineering, from basic principles to applications. The focus is on the science and engineering, and includes environmental impact and some economics considerations. A review of energy consumption, use, and resources; sustainability, methods of energy and exergy (second law) analysis; power cycles, combined cycles, and co-generation; batteries and fuel cells; nuclear energy and wastes; fusion power; solar energy; power generation in space.

504. Tribology. Prerequisite(s): Junior or Senior standing in engineering. Freshman Chemistry, Fluid Mechanics (MEAM 302) or by permission from instructor.

The course will present comprehensive coverage of theoretical and practical tribology, the science and technology of interacting surfaces in relative motion. The various modes of lubrication, hydrodynamic, elastohydrodynamic, hydrostatic and boundary, will be studied in detail. The contact between solid surfaces will be covered, leading to an understanding of friction and various modes of wear. At each stage, it will be shown how the tribological principles learned can be applied in practice to improve the efficiency and durability of mechanical equipment.

505. (MEAM 405, MSE 405, MSE 505) Mechanical Properties of Macro/Nanoscale Materials.

The application of continuum and microstructural concepts to consideration of the mechanics and mechanisms of flow and fracture in metals, polymers and ceramics. The course includes a review of tensors and elasticity with special emphasis on the effects of symmetry on tensor properties. Then deformation, fracture and degradation (fatigue and wear) are treated, including mapping strategies for understanding the ranges of material properties.

509. Mechanics of Human Motion.

This course considers normal human movement (especially grasping, reaching, walking, and running), pathological conditions (e.g., resulting from disease, injury, malformations), and engineering approaches such as prostheses (limb replacements) and orthoses (limb assists) that may ameliorate the conditions and promote normal movements and function. In doing so, we will also learn musculoskeletal anatomy, comparative anatomy, muscle mechanics, and neural control. An objective of the course is to bring together technical analysis and synthesis skills of students with the practical problems of persons disabled by amputation, stroke, spinal cord injury, and other causes. The potential problems of applying engineering techniques to human beings will be emphasized. Engineering design comprises that are necessary are also given emphasis.

510. (MEAM 410) Design of Mechatronic Systems II. Prerequisite(s): Graduate standing in engineering, or permission from instructor.

In many modern systems, mechanical elements are tightly coupled with electronic components and embedded computers. Mechatronics is the study of how these domains are interconnected, and this hands-on, project-based course provides an integrated introduction to the fundamental components within each of the three domains, including: mechanical elements (prototyping, materials, actuators and sensors, transmissions, and fundamental kinematics), electronics (basic circuits, filters, op amps, discrete logic, and interfacing with mechanical elements), and computing (interfacing with the analog world, microprocessor technology, basic control theory, and programming).

511. (IPD 511) Creative Thinking and Design.

This is a creative & iterative problem solving course that uses a series of mechanical design challenge projects to move students into the broad realm of unpredictable often incalculable time-constrained problem solving. It explores a wide variety of problem definition, exploration and solving “tools,” and a variety of surrounding “design thinking” topics, such as ethics and the design of experience. Drawing and prototyping are used in the projects for ideation, iteration, speculation and communication.

513. (ESE 406, ESE 505) Modern Feedback Control Theory. Prerequisite(s): ESE 210. Juniors and Seniors encouraged to enroll. Sophomores require permission.

Basic methods for analysis and design of feedback control in systems. Applications to practical systems. Methods presented include time response analysis, frequency response analysis, root locus, Nyquist and Bode plots, and the state-space approach.

514. (IPD 514) Design for Manufacturability.

Prerequisite(s): Senior or Graduate standing in the School of Design, Engineering, or Business with completed product development and/or design engineering core coursework or related experience.

This course is aimed at providing current and future product design/development engineers, manufacturing engineers, and product development managers with an applied understanding of Design for Manufacturability (DFM) concepts and methods. The course content includes materials from multiple disciplines including: engineering design, manufacturing, marketing, finance, project management, and quality systems.

515. (IPD 515, OPIM 415) Product Design.

This course provides tools and methods for creating new products. The course is intended for students with a strong career interest in new product development, entrepreneurship, and/or technology development. The course follows an overall product methodology, including the identification of customer needs, generation of product concepts, prototyping, and design-for-manufacturing. Weekly student assignments are focused on the design of a new product and culminate in the creation of a prototype. The course is open to juniors and seniors in SEAS or Wharton.

516. (IPD 516) Advanced Mechatronic Reactive Spaces. (B)

This course teaches advanced mechatronics concepts that include the design and implementation of networked embedded systems, large-scale actuation, advanced sensing and control. This course pairs design school and engineering students to form interdisciplinary teams that together design and build electro-mechanical reactive spaces and scenic/architectural elements in the context of the performing arts. The two disciplinary groups will be treated separately and receive credit for different courses (ARCH746 will be taught concurrently and in some cases co-located) as they will be learning different things. Engineering students gain design sensibilities and advanced mechatronics in the form of networked embedded processing and protocols for large scale actuation and sensing. Design students learn elementary mechatronics and design reactive architectures and work with engineering students to build them. The class will culminate in a collection of short performance pieces inspired by Shakespeare's A Midsummer Night's Dream with both mechatronic and human performers from the Pig Iron Theater Troupe. A final paper will be required that is ready for conference proceedings.

519. (MSE 550) Elasticity and Micromechanics of Materials.

This course is targeted to engineering students working in the areas on micro/nanomechanics of materials. The course will start with a quick review of the equations of linear elasticity and proceed to solutions of specific problems such as the Hertz contact problem, Eshelby's problem etc. Failure mechanisms such as fracture and the fundamentals of dislocations/plasticity will also be discussed.

520. Robotics. Prerequisite(s): Graduate standing in engineering or permission of instructor.

The rapidly evolving field of robotics includes systems designed to replace, assist, or even entertain humans in a wide variety of tasks. Recent examples include planetary rovers, robotic pets, medical surgical-assistive devices, and semi-autonomous search-and-rescue vehicles. This introductory-level course presents the fundamental kinematic, dynamic, and computational principles underlying most modern robotic systems. The main topics of the course include: coordinate transformations, manipulator kinematics, mobile-robot kinematics, actuation and sensing, feedback control, vision, motion planning, and learning. The material is reinforced with hands-on lab exercises including basic robot-arm control and the programming of vision-guided mobile robots.

521. Introduction to Parallel Computing for Scientific Applications. Prerequisites: Programming. Familiarity with Linux or Unix will help.

From numerical weather prediction and earthquake simulations, to quantum mechanics, and to genome sequencing and molecular dynamics, high-performance computing (HPC) is a fundamental tool for science. The basic principles on how to design, implement, and evaluate HPC techniques will be covered. Topics include parallel non-numerical and numerical algorithms, computing platforms, and message passing interface. Science applications will sample techniques applied to partial differential equations, many-body problems, and statistical physics. Practical problem-solving and hands-on examples will be a basic part of the course.

MEAM 527. (EMM 427) Finite Elements and Applications. Prerequisite(s): MATH 241 and PHYS 151.

The objective of this course is to equip students with the background needed to carry out finite elements-based simulations of various engineering problems. The first part of the course will outline the theory of finite elements. The second part of the course will address the solution of classical equations of mathematical physics such as Laplace, Poisson, Helmholtz, the wave and the Heat equations. The third part of the course will consist of case studies taken from various areas of engineering and the sciences on topics that require or can benefit from finite element modeling. The students will gain hand-on experience with the multi-physics, finite element package FemLab.

529. (ESE 529) Introduction to MEMS and NEMS.

Introduction to RM MEMS technologies; need for RF MEMS components in wireless communications. Review of micromachining techniques and MEMS fabrication approaches. Actuation methods in MEMS, TRF MEMS design and modeling. Examples of RF MEMS components from industry and academia. Case studies: micro-switches, tunable capacitors, inductors, resonators, filters, oscillators and micromachined antennas. Overview of RF NEMS.

530. Continuum Mechanics.

Prerequisite(s): Multivariable Calculus, Linear Algebra, Partial Differential Equations.

This course serves as a basic introduction to the Mechanics of Continuous Media and it will prepare the student for more advanced courses in Solid and Fluid Mechanics. The topics to be covered include: Tensor Algebra and Calculus; Lagrangian and Eulerian Kinematics; Cauchy and Piola-Kirchhoff Stresses; General principles, Conservation of Mass, Conservation of Linear and Angular Momentum, Energy and the First Law of Thermodynamics, Entropy and the Second Law of Thermodynamics; Constitutive Theory, Ideal Fluids, Newtonian and non-Newtonian Fluids, Finite Elasticity, Linear Elasticity, Materials with Microstructure.

535. Advanced Dynamics.

Rigid body kinematics; Newtonian formulations of laws of motion; concepts of momentum, energy and inertia properties; generalized coordinates, holonomic and nonholonomic constraints. Generalized forces, principle of virtual work, D'Alembert's principle. Lagrange's equations of motion and Hamilton's equations. Conservation laws and integrals of motion. Friction, impulsive forces and impact. Applications to systems of rigid bodies.

537. Nanomechanics and Nanotribology. Prerequisites: Freshman physics; MEAM 354 or equivalent, or consent of instructor.

Engineering is progressing to ever smaller scales, enabling new technologies, materials, devices, and applications. Mechanics enters a new regime where the role of surfaces, interfaces, defects, material property variations, and quantum effects play more dominant roles. This course will provide an introduction to nano-scale mechanics and tribology at interfaces, and the critical role these topics play in the developing area of nanoscience and nanotechnology. We will discuss how mechanics and tribology at interfaces become integrated with the fields of materials science, chemistry, physics, and biology at this scale. We will cover a variety of concepts and applications, drawing connections to both established and new approaches. We will discuss the limits of continuum mechanics and present newly developed theories and experiments tailored to describe micro- and nano-scale phenomena. We will emphasize specific applications throughout the course. Literature reviews, critical peer discussion, individual and team problem assignments, a laboratory project, and student presentations will be assigned as part of the course.

544. (BE 455, MEAM 455) Continuum Biomechanics. Prerequisite(s): Statics, linear algebra, and differential equations.

Biological and non-biological systems are both subject to several basic physical balance laws of broad engineering importance. Fundamental conservation laws are introduced and illustrated using examples from both animate as well as inanimate systems. Topics include kinematics of deformation, the concept of stress, conservation of mass, momentum, and energy. Mechanical constitutive equations for fluids, solids and intermediate types of media are described and complemented by hands-on experimental and computational laboratory experiences. Practical problem solving using numerical methods will be introduced.

545. Aerodynamics. Prerequisite(s): MEAM 302.

Review of fluid kinematics and conservation laws; vorticity theorems; two-dimensional potential flow; airfoil theory; finite wings; oblique shocks; supersonic wing theory; laminar and turbulent boundary layers.

554. (MEAM 454) Mechanics of Materials. Prerequisite(s): MEAM 210, MATH 240, 241.

Rods and Trusses. Stress. Principal Stresses. Strain. Compatibility. Elastic Stress-Strain Relations. Strain Energy. Plane Strain. Plane Stress. Bending of Beams. Torsion. Rotating Disks. Castigliano's Theorem. Dummy Loads. Principle of Virtual Work. The Rayleigh-Ritz Methods. Introduction to the Finite Element Method. Non-Linear Material Behavior. Yielding. Failure.

555. (CBE 555, BE 555) Nanoscale Systems Biology. Prerequisite(s): Background in Biology, Chemistry or Engineering with coursework in thermodynamics or permission of instructor.

From single molecule studies to single cell manipulations, the broad field of cell and molecular biology is becoming increasingly quantitative and increasingly a matter of systems simplification and analysis. The elaboration of various stresses on cellular structures, influences of interaction pathways and convolutions of incessant thermal motions will be discussed via lectures and laboratory demonstration. Topics will range from, but are not limited, to protein folding/forced unfolding to bimolecular associations, cell and membrane mechanics, and cell motility, drawing from very recent examples in the literature. Frequent hands-on exposures to modern methods in the field will be a significant element of the course in the laboratory. Skills in analytical and professional presentations, papers and laboratory work will be developed.

561. Thermodynamics I. Prerequisite(s): Undergraduate thermodynamics.

To introduce students to advanced classical equilibrium thermodynamics based on Callen's postulational approach, to exergy (Second-Law) analysis, and to fundamentals of statistical and nonequilibrium thermodynamics. Applications to be discussed include advanced power and aerospace propulsion cycles, fuel cells, combustion, diffusion, transport in membranes, materials properties, superconductivity, elasticity, and biological processes.

564. (ESE 460/574) The Principles and Practice of Microfabrication Technology. Prerequisite(s): Any of the following courses: ESE 218, MSE 321, MEAM 333, CBE 351, CBEM 321/322, Phys 250 or permission of the instructor.

A laboratory course on fabricating microelectronic and micromechanical devices using photolithographic processing and related fabrication technologies. Lectures discuss: clean room procedures; microelectronic and microstructural materials; photolithography; diffusion; oxidation, materials deposition; etching and plasma processes. Basic laboratory processes are covered in the first two thirds of the course with students completing structures appropriate to their major in the final third. Students registering for ESE 574 will be expected to do extra work (including term paper and additional project).

570. (CBE 640) Transport Processes I.

The course provides a unified introduction to momentum, energy (heat), and mass transport processes. The basic mechanisms and the constitutive laws for the various transport processes will be delineated, and the conservation equations will be derived and applied to internal and external flows featuring a few examples from mechanical, chemical, and biological systems. Reactive flows will also be considered.

571. Advanced Topics in Transport Phenomena. Prerequisite(s): Either MEAM 570, MEAM 642, CHE 640 or equivalent, or written permission of the Instructor.

The course deals with advanced topics in transport phenomena and is suitable for graduate students in mechanical, chemical and bioengineering who plan to pursue research in areas related to transport phenomena or work in an industrial setting that deals with transport issues. Topics include: Multi-component transport processes; Electrokinetic phenomena; Phase change at interfaces: Solidification, melting, condensation, evaporation, and combustion; Radiation heat transfer: properties of real surfaces, non-participating media, gray medium approximation, participating media transport, equation of radiative transfer, optically thin and thick limits, Monte-Carlo methods: Microscale energy transport in solids; microstructure, electrons, phonons, interactions of photons with electrons, phonons and surfaces; microscale radiation phenomena.

572. Micro/Nanoscale Energy Transport. Prerequisite: Undergraduate thermodynamics and heat transfer (or equivalent), or permission of the instructor. Undergraduates may enroll with permission of the instructor.

As materials and devices shrink to the micro- and nanoscale, they transmit heat, light, and electronic energy much differently than at macroscopic length scales. This course provides a foundation for studying the transport of thermal, optical, and electronic energy from a microscopic perspective. Concepts from solid state physics and statistical mechanics will be introduced to analyze the influence of small characteristic dimensions on the propagation of crystal vibrations, electrons, photons, and molecules. Applications to modern microdevices and thermometry techniques will be discussed. Topics to be covered include natural and fabricated microstructures, transport and scattering of phonons and electrons in solids, photonphonon and photon-electron interactions, radiative recombinations, elementary kinetic theory, and the Boltzmann transport equation.

575. Micro and Nano Fluidics.

The course will focus on a few topics relevant to micro-fluidics and nano-technology. In particular, we will learn how the solid liquid interface acquires charge and the role that this charge plays in colloid stability, electroosmosis, and electrophoresis. Other topics will include controlled nano-assembly with dielectrophoresis, and stirring at very low Reynolds numbers (Lagrangian Chaos). The focus of the course will be on the physical phenomena from the continuum point of view. The mathematical complexity will be kept to a minimum. Software tools such as Maple and Femlab will be used throughout the course. The course will be reasonably self-contained and necessary background material will be provided consistent with the students' level of preparation.

PRIMARY FACULTY IN MECHANICAL ENGINEERING AND APPLIED MECHANICS

As of 9/5/10

Paulo E. Arratia, Assistant Professor

Office: 271 Towne Phone: 215-746-2174 Email: parratia@seas

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.

Portonovo S. Ayyaswamy, Asa Whitney Professor of Dynamical Engineering

Office: 231 Towne Phone: 215-898-8362 Email: ayya@seas

Phase change heat and mass transfer processes, bioheat/mass transfer, arc-plasma heat transfer, thermal aspects in MEMS.

John L. Bassani, Chair and Richard H. and S.L. Gabel Professor of Mechanical Engineering

Office: 237 Towne Phone: 898-5632 Email: bassani@seas

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 and Undergraduate Curriculum Chair

Office: 233 Towne Phone: 215-898-8363 Email: bau@seas

Bifurcation and instability phenomena in and feedback control of flows, transport phenomena in micron and submicron size structures, meso- and microelectromechanical systems.

Robert Carpick, Professor

Office: 251 Towne Phone: 215-898-4608 Email: carpick@seas

Experimental nanomechanics and nanotribology (friction, adhesion, lubrication, wear). Development, characterization, and applications of nanostructured materials. Application and development of advanced scanning force microscopy tools.

Howard H. Hu, Professor

Office: 241 Towne Phone: 215-898-8504 Email: hhu@seas

Modeling of complex flows with multiphase or polymeric fluids, computational fluid dynamics, hydrodynamic stability.

Katherine J. Kuchenbecker, Skirkanich Assistant Professor of Innovation in Mechanical Engineering and Applied Mechanics

Office: 224 Towne Phone: 215-573-2786 Email: kuchenbe@seas

Haptic (touch-based) interaction; design and control of haptic interfaces for virtual environments and teleoperation; identification of dynamic systems; understanding human upper-limb movement; developing medical devices and medical robotic systems.

Vijay Kumar, Deputy Dean for Education and Professor
Office: 470 Levine Phone: 215-898-3630 Email: kumar@grasp

Robotics, dynamics of systems with frictional contacts, actively coordinated mobility systems, mechanism design and control.

Noam Lior, Professor
Office: 212 Towne Phone: 215-898-4803 Email: lior@seas

Heat transfer and fluid mechanics, thermodynamics and Second-Law analysis, energy conversion, solar energy, combustion, flash evaporation and water desalination, destruction of hazardous wastes by photocatalysis and supercritical oxidation, heat treatment.

Jennifer R. Lukes, Associate Professor and Graduate Group Chair
Office: 247 Towne Phone: 215-898-3254 Email: jrlukes@seas

Molecular dynamics simulation, molecular mechanical engineering, micro/nanoscale heat transfer.

Pedro Ponte Castañeda, Professor
Office: 235 Towne Phone: 215-898-5046 Email: ponte@seas

Nonlinear composite materials, fracture mechanics, microstructure evolution and localization in manufacturing processes, nonlinear variational principles in mechanics.

Prashant Purohit, Assistant Professor
Office: 239 Towne Phone: 215-898-3870 Email: purohit@seas

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

Mark Yim, Associate Professor
Office: 229A Towne Phone: 215-898-5269 Email: yim@grasp.cis

Modular reconfigurable robots and locomotion, PolyBot; MEMS and batch fabrication techniques; brute force digital time optimal control.

AFFILIATED FACULTY AND LECTURERS

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Thomas A.V. Cassel, Professor of Practice
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STAFF

As of 9/05/10

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Peter Rockett, Instructional/Experimental Machinist
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Peter Szczesniak, Instructional Laboratory Coordinator
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University of Pennsylvania's Code of Academic Integrity

Since the University is an academic community, its fundamental purpose is the pursuit of knowledge. Essential to the success of this educational mission is a commitment to the principles of academic integrity. Every member of the University community is responsible for upholding the highest standards of honesty at all times. Students, as members of the community, are also responsible for adhering to the principles and spirit of the following Code of Academic Integrity.*

Academic Dishonesty Definitions

Activities that have the effect or intention of interfering with education, pursuit of knowledge, or fair evaluation of a student's performance are prohibited. Examples of such activities include but are not limited to the following definitions:

A. Cheating

Using or attempting to use unauthorized assistance, material, or study aids in examinations or other academic work or preventing, or attempting to prevent, another from using authorized assistance, material, or study aids. Example: using a cheat sheet in a quiz or exam, altering a graded exam and resubmitting it for a better grade, etc.

B. Plagiarism

Using the ideas, data, or language of another without specific or proper acknowledgment. Example: copying another person's paper, article, or computer work and submitting it for an assignment, cloning someone else's ideas without attribution, failing to use quotation marks where appropriate, etc.

C. Fabrication

Submitting contrived or altered information in any academic exercise. Example: making up data for an experiment, fudging data, citing nonexistent articles, contriving sources, etc.

D. Multiple Submissions

Multiple submissions: submitting, without prior permission, any work submitted to fulfill another academic requirement.

E. Misrepresentation of academic records

Misrepresentation of academic records: misrepresenting or tampering with or attempting to tamper with any portion of a student's transcripts or academic record, either before or after coming to the University of Pennsylvania. Example: forging a change of grade slip, tampering with computer records, falsifying academic information on one's resume, etc.

F. Facilitating Academic Dishonesty

Knowingly helping or attempting to help another violate any provision of the Code. Example: working together on a take-home exam, etc.

G. Unfair Advantage

Attempting to gain unauthorized advantage over fellow students in an academic exercise. Example: gaining or providing unauthorized access to examination materials, obstructing or interfering with another student's efforts in an academic exercise, lying about a need for an extension for an exam or paper, continuing to write even when time is up during an exam, destroying or keeping library materials for one's own use., etc.

* If a student is unsure whether his action(s) constitute a violation of the Code of Academic Integrity, then it is that student's responsibility to consult with the instructor to clarify any ambiguities.