



**UNDERGRADUATE STUDENT MANUAL**

**Department of Mechanical Engineering  
and Applied Mechanics**

**University of Pennsylvania**

**September 2012**

*[www.me.upenn.edu](http://www.me.upenn.edu)*

## TABLE OF CONTENTS

What is Mechanical Engineering and Applied Mechanics? .....	3
Advising and Degree Information .....	4
Student Organizations.....	5
Curriculum in Mechanical Engineering and Applied Mechanics.....	6
Course Planning Guide (CPG).....	7
B.S.E. Sample Four-Year Course Plan .....	8
MEAM Concept Flowchart .....	9
MEAM Elective Schedule .....	10
Recommended Electives outside of MEAM.....	11
Areas of Specialization .....	12
Course Descriptions .....	14
Primary Faculty and Their Research .....	22
Affiliated Faculty and Lecturers .....	24
Staff.....	25
Code of Academic Integrity .....	26

## **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, structure mechanics or cross-disciplinary areas as robotics, biomechanics, micro-electromechanical systems (MEMS), and 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. Students must meet with their advisor at least once each semester. Students in academic difficulties should meet with their advisor as soon as they identify that they have academic problems.

### **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.

### **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, except MEAM 445 and 446 (Senior Design). At most two course units may be at the 100 level (i.e., MEAM 1XX). Up to two cognate courses can be substituted for MEAM courses. See the departmental website for an up-to-date listing of cognate courses:

<http://www.me.upenn.edu/prospective-students/undergraduates/majors-minors.php#minor>

## 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/](http://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 coordinate a variety of academic, professional and social activities.

**President:** Elizabeth Beattie, [ebeattie@seas.upenn.edu](mailto:ebeattie@seas.upenn.edu)

**Faculty Advisor:** Prof. Mark Yim, [yim@seas.upenn.edu](mailto:yim@seas.upenn.edu)



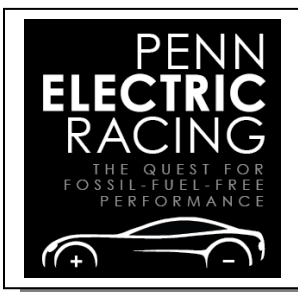
### **Formula SAE Car**

[www.seas.upenn.edu/~fsae/](http://www.seas.upenn.edu/~fsae/)

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

**Captain:** Karan Desai, [karand@seas.upenn.edu](mailto:karand@seas.upenn.edu)

**Faculty Advisor:** Prof. Robert Jeffcoat, [rlj@seas.upenn.edu](mailto:rlj@seas.upenn.edu)



### **Penn Electric Racing**

[www.seas.upenn.edu/~electric/](http://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:** Oliver Pacchiana, [opacc@seas.upenn.edu](mailto:opacc@seas.upenn.edu)

**Faculty Advisor:** Prof. Robert Jeffcoat, [rlj@seas.upenn.edu](mailto:rlj@seas.upenn.edu)

## **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: [www.me.upenn.edu/current-students/undergraduates/degree-requirements.php](http://www.me.upenn.edu/current-students/undergraduates/degree-requirements.php)
- Penn InTouch: [https://medley.isc-seo.upenn.edu/penn\\_portal/intouch/splash.html](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](http://www.seas.upenn.edu/undergraduate/handbook/courses/math-courses.php)

- MATH 104 Calculus I (Section 7 is recommended)
- MATH 114 Calculus II
- MATH 240 Calculus III
- MATH 241 Calculus IV or ENM 251
- \_\_\_\_\_<sup>1</sup>

1. Recom: EAS 205 Applications of Scientific Comp

### Natural Science (5 CU)

[www.seas.upenn.edu/undergraduate/handbook/courses/nat-science-courses.php](http://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
- \_\_\_\_\_<sup>2</sup>

2. Recom: BIOL 101 Intro. To Biology  
 BIOL 121 Intro Bio-Molec Bio Life  
 PHYS 280 Biological Physics  
 MSE 221 Quantum Physics of Materials

### Core MEAM (10 CU)

- MEAM 203 Thermodynamics I
- MEAM 210 Statics & Str. of Materials
- MEAM 211 Eng Mechanics: Dynamics
- MEAM 247 MEAM Lab I
- MEAM 248 MEAM Lab I
- 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)<sup>3</sup>

- MEAM 445 Design Project I
- MEAM 446 Design Project II
- EAS 105 Intro to Scientific Computing<sup>4</sup>
- MEAM Upper level \_\_\_\_\_<sup>5</sup>
- MEAM Upper level \_\_\_\_\_<sup>5</sup>
- MEAM Upper level \_\_\_\_\_<sup>5</sup>
- Professional Elective \_\_\_\_\_<sup>6</sup>
- Professional Elective \_\_\_\_\_<sup>6</sup>
- Professional Elective \_\_\_\_\_<sup>6, 7</sup>
- Professional Elective \_\_\_\_\_<sup>6, 7</sup>

3. Max of three 100-level courses.  
 4. CIS 110, CIS 120 or ESE 112 are also acceptable.  
 5. MEAM 405, 410, 454, 455, 502, 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)<sup>8,9</sup>

[www.seas.upenn.edu/undergraduate/handbook/courses/ssh-breadth.php](http://www.seas.upenn.edu/undergraduate/handbook/courses/ssh-breadth.php)

[www.seas.upenn.edu/undergraduate/handbook/courses/tech-bus-courses.php](http://www.seas.upenn.edu/undergraduate/handbook/courses/tech-bus-courses.php)

- SS \_EAS 203 (recommended)\_       H \_\_\_\_\_
- SS \_\_\_\_\_       H \_\_\_\_\_
- SS or H \_\_\_\_\_       SS, H or TBS \_\_\_\_\_
- SS, H or TBS \_\_\_\_\_

8. Two of these electives must be taken in the same department. This fulfills the **Depth Requirement**:  
[www.seas.upenn.edu/undergraduate/handbook/courses/ssh-depth.php](http://www.seas.upenn.edu/undergraduate/handbook/courses/ssh-depth.php)

9. One of these electives must fulfill the **Writing Requirement**:  
[www.seas.upenn.edu/undergraduate/handbook/courses/writing-requirement.php](http://www.seas.upenn.edu/undergraduate/handbook/courses/writing-requirement.php)

### Free Electives (3 CU)

[www.seas.upenn.edu/undergraduate/handbook/courses/free-elective.php](http://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

CUs			CUs		
FALL			SPRING		
1.5	<b>MEAM 110/147</b>	Intro to Mechanics & Lab	1.5	<b>PHYS 151</b>	Principles of Physics II & Lab
1	<b>MATH 104-007</b>	Calculus I	1	<b>MATH 114-002</b>	Calculus II
1.5	<b>CHEM 101/053</b>	Intro to Chemistry & Lab	1	Professional elective (e.g., EAS 105 or MEAM 101)	
1	Elective: Social Science/Humanities		1	Writing Requirement	
<b>Note: Students with AP credit may take EAS 105 or MEAM 101 in lieu of MEAM110 or MATH104</b>			1	Natural Science elective	

### Sophomore Year

CUs			CUs		
FALL			SPRING		
1	EAS 105	Intro to Scien. Comp.	1	<b>MEAM 203</b>	Thermodynamics I
1	<b>MEAM 210</b>	Statics and Strength of Materials	1	<b>MEAM 211</b>	Engineering Mechanics: Dynamics
.5	<b>MEAM 247</b>	Mechanical Engineering Laboratory I	.5	<b>MEAM 248</b>	Mechanical Engineering Laboratory I
1	<b>MATH 240</b>	Calculus III	1	<b>MATH 241 or ENM 251</b>	Calculus IV or Analytical Methods for Eng
1	Professional elective		1	Social Science/Humanities elective	
1	Social Science/Humanities elective (e.g., EAS 203)				

### Junior Year

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

### Senior Year

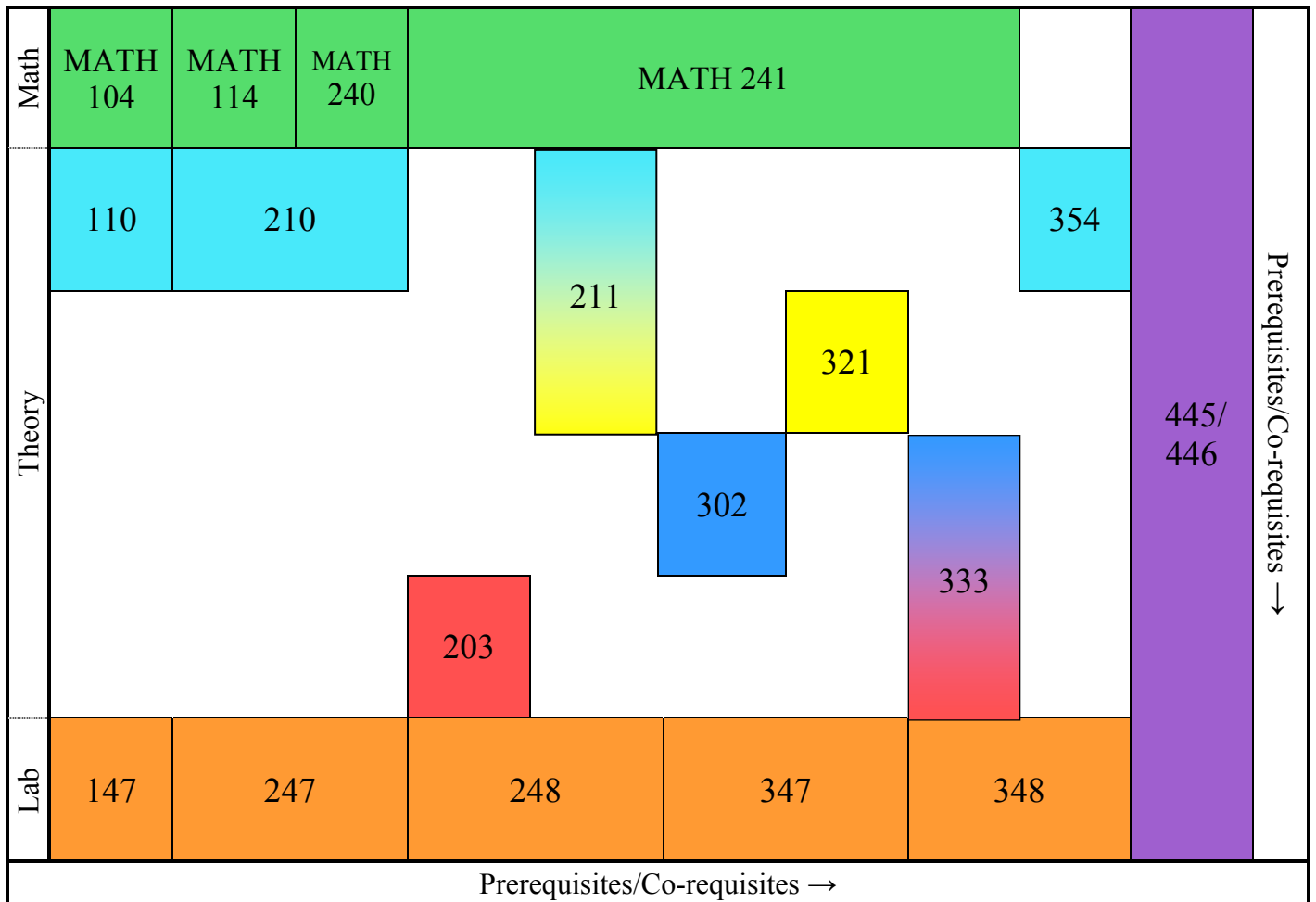
CUs			CUs		
FALL			SPRING		
1	<b>MEAM 445</b>	Mechanical Engineering Design Projects	1	<b>MEAM 446</b>	Mechanical Engineering Design Projects
1	Upper-level MEAM course		1	Upper-level MEAM course	
1	Professional elective		1	Professional elective	
1	Social Science/Humanities /TBS elective		1	Social Science/Humanities /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.

## MEAM ELECTIVE SCHEDULE

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

### **Fall 2012 Electives**

MEAM 101	Intro to Mechanical Design
MEAM 201	Machine Design and Manufacturing
MEAM 245	Intro to Flight
MEAM 405/505	Mechanical Properties of Macro/Nanoscale Materials
MEAM 410/510	Design of Mechatronic Systems
MEAM 415, IPD 515, OPIM 415	Product Design
MEAM 502	Energy Engineering
MEAM 520	Intro to Robotics
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 250	Energy Systems, Resources and Technology
EAS 401/501	Energy and its Impacts
EAS 545	Engineering Entrepreneurship I
EAS 546	Engineering Entrepreneurship II

### **Tentative Spring 2013 Electives**

MEAM 101	Intro to Mechanical Design
MEAM 201	Machine Design and Manufacturing
MEAM 415, IPD 515, OPIM 415	Product Design
MEAM 454/554	Mechanics of Materials
MEAM 504	Enhancing Sustainability through Tribology
MEAM 513	Modern Feedback Control Theory
MEAM 514, IPD 514	Design for Manufacturability
MEAM 516	Advanced Mechatronics
MEAM 545	Aerodynamics
MEAM 553	Atomic Models in Materials Science
EAS 105	Intro to Scientific Computing
EAS 250	Energy Systems, Resources and Technology
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

## **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
MSE 221	Quantum Physics of 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 502	Energy Engineering
MEAM 570	Transport
MEAM 572	Micro/Nanoscale Energy Transport
EAS 250	Energy Systems, Resources & Technology
EAS 401/501	Energy and Its Impacts
EAS 402/502	Renewable Energy and Its Impacts

**Fluid Mechanics and Aerodynamics**

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

**Manufacturing**

MEAM 101	Introduction to Computer Aided Design and Manufacturing
MEAM 201	Machine Design and Manufacturing
MEAM 410/510	Design of Mechatronic Systems
MEAM 415, IPD 515, OPIM 415	Product Design
ENM 427/MEAM 527	Finite Element and Applications
MEAM 454/554	Mechanics of Materials
MEAM 520	Robotics
MEAM 564	Principles of Microfabrication Technology
ESE 215	Electrical Circuits and Systems
ESE 522	Process Mgmt in Manufacturing

**Mechatronics**

MEAM 410/510	Design of Mechatronic Systems
MEAM 516	Advanced Mechatronics
MEAM 520	Intro to 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 201	Machine Design and Manufacturing
MEAM 410/510	Design of Mechatronic Systems
MEAM 415, IPD 515, OPIM 415	Product Design
MEAM 514, IPD 514	Design for Manufacturability
EAS 545	Engineering Entrepreneurship I
EAS 546	Engineering Entrepreneurship II
ESE 400/540	Engineering Economics

### **Structural Mechanics & Mechanics of Materials**

ENM 427/MEAM 527	Finite Element and Applications
MEAM 454/554	Mechanics of Materials
MEAM 519/MSE 550	Introduction to Elasticity
MEAM 530	Continuum Mechanics
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.

### **201. Machine Design and Manufacturing.** Prerequisite(s): MEAM101 recommended, MEAM 210 or equivalent as co/pre-requisite (or permission from instructor).

Building upon the fundamentals of mechanical design taught in MEAM 101, this hands-on, project-based course provides students with the knowledge and skills necessary to design, analyze, manufacture, and test fully-functional mechanical systems. Topics covered include an introduction to machine elements, analysis of the mechanics of machining, manufacturing technology, precision fabrication (milling, turning, and computer-controlled machining), metrology, tolerances, cutting-tool fundamentals, and engineering materials. Enrollment is limited.

### **203. Thermodynamics I.** Prerequisite(s): MATH 240

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. Co-requisite: MATH 241 or ENM 251 and EAS 105 or equivalent.

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.

**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 is strongly recommended.

Following closely with MEAM 210, this Sophomore-level course covers the principles of experimentation and measurement systems in a design-laboratory setting, wherein students will explore the principles of statics and strength of materials.

**248. Mechanical Engineering Laboratory I.** Prerequisite(s): Sophomore standing in engineering. Corequisite(s): MEAM 203 and MEAM 211 are strongly recommended.

Following closely with both MEAM 203 and MEAM 211, this Sophomore-level course covers the principles of experimentation and measurement systems in a design-laboratory setting, wherein students will explore the principles of dynamics and thermodynamics.

**302. Fluid Mechanics.** Prerequisite(s): MATH 241 or ENM 251 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.

**321. Vibrations of Mechanical Systems.** Prerequisite(s): MATH 241 or ENM 251 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 or ENM 251 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.

**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.

**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).

**415. (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.

**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 interested 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. 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 of power generation. The course a review of energy resources and consumption, power cycles, combined cycles, and co-generation, nuclear energy and wastes, solar thermal and photovoltaic energy, and wind power. Additional energy conversion topics including energy storage and geothermal, thermoelectric, hydroelectric and biomass power will be briefly discussed.

**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.

**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).

**513. (ESE 406, ESE 505) Modern Feedback Control Theory.** Prerequisite(s): MEAM 321 or ESE 210. Juniors and Seniors encouraged to enroll.

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): MEAM 101 or equivalent, MEAM 210 or equivalent, 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.

**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. Intro to Robotics.** Prerequisite(s): MEAM 211 and MATH 240 or equivalent.

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, and motion planning. The material is reinforced with hands-on lab exercises including robot-arm control and the programming of vision-guided mobile robots.

**527. (EMM 427) Finite Elements and Applications.** Prerequisite(s): MATH 241 or ENM 251 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.

**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.

**550. Design of Micro-Electro-Mechanical Systems.** Prerequisites: MEAM 527 or equivalent is recommended. Undergraduates need permission.

Introduction to Micro-Electro-Mechanical Systems (MEMS). Modeling and multi-energy domain coupled simulations of MEMS devices and systems using simple analytical models as well as state-of-the-art methods and software. Designing MEMS devices for a Surface Micromachining "foundry" process: from paper designs to real devices. Nonlinear dynamics of electrostatically actuated MEMS devices. Synthesis of compliant micro structures. Review of selected papers from the literature. A term-project that includes design and fabrication (at an external "foundry" facility) of a micro device, and a term-paper on a selected topic are required.

**553. (MSE 561) Atomistic Modeling in Materials Science.**

Why and what to model: Complex lattice structures, structures of lattice defects, crystal surfaces, interfaces, liquids, linking structural studies with experiential observations, computer experiments. Methods: Molecular statics, molecular dynamics, Monte Carlo. Evaluation of physical quantities employing averages, fluctuations, correlations, autocorrelations, radial distribution function, etc. Total energy and interatomic forces: Local density functional theory and abinitio electronic structure calculations, tight-binding methods, empirical potentials for metals, semiconductors and ionic crystals.

**554. (MEAM 454) Mechanics of Materials.** Prerequisite(s): MEAM 210, MEAM 354, 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 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.

**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. 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 9/1/12

**Paulo E. Arratia**, Associate 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.upenn.edu

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

**Igor Bargatin**, Adjunct Assistant Professor; Class of 1965 Term Assistant Professor (starting Jan 2013)

Office: TBD Phone: TBD Email: bargatin@seas.upenn.edu

Micro- and nanomechanics, thermal sciences and energy conversion, mechanics of materials.

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

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

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.upenn.edu

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

**Robert Carpick**, Chair and Professor

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

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.upenn.edu

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.upenn.edu

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**, UPS Foundation Professor

Office: 470 Levine Phone: 215-898-3630 Email: kumar@seas.upenn.edu

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.upenn.edu

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.upenn.edu

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

**Pedro Ponte Castañeda**, Professor

Office: 235 Towne Phone: 215-898-5046 Email: ponte@seas.upenn.edu

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

**Prashant Purohit**, Associate Professor

Office: 239 Towne Phone: 215-898-3870 Email: purohit@seas.upenn.edu

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

**David J. Srolovitz**, Joseph Bordogna Professor of Engineering and Applied Science (in MEAM and MSE);  
Director of the Penn Center of Excellence in Advanced Computation

Office: 409 LRSM Phone: 215-898-8337 Email: srol@seas.upenn.edu

Computational and theoretical materials science, Defects, Growth, Evolution and deformation of materials

**Kevin Turner**, Gabel Family Term Associate Professor of Mechanical Engineering

Office: 245 Towne Phone: 215-573-7485 Email: kturner@seas.upenn.edu

Development and understanding of micro/nanoscale manufacturing processes, experimental and computational fracture and contact mechanics, small-scale adhesion mechanics, micro/nanoelectromechanical systems, mechanics of biological interfaces and cells

**Mark Yim**, Professor and Director of the Integrated Product Design Program

Office: 229A Towne Phone: 215-898-5269 Email: yim@seas.upenn.edu

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

## AFFILIATED FACULTY AND LECTURERS

As of 9/01/12

**Jeffrey Babin**, Senior Lecturer and Associate Director of the Entrepreneurship Program  
Office: 308 Towne Phone: 573-0731 Email: [jbabin@seas.upenn.edu](mailto:jbabin@seas.upenn.edu)

**Peter Bressler**, Adjunct Associate Professor  
Office: 210 Towne Phone: 215-898-3108 Email: [pwbe@seas.upenn.edu](mailto:pwbe@seas.upenn.edu)

**Michael Carchidi**, Senior Lecturer  
Office: 208 Towne Phone: 215-898-8342 Email: [carchidi@seas.upenn.edu](mailto:carchidi@seas.upenn.edu)

**Thomas A.V. Cassel**, Professor of Practice and Director of the Entrepreneurship Program  
Office: 306 Towne Phone: 215-573-9016 Email: [tcassel@seas.upenn.edu](mailto:tcassel@seas.upenn.edu)

**Albert Cho**, Lecturer  
Office: 210 Towne Phone: 215-746-4410 Email: [alcho@seas.upenn.edu](mailto:alcho@seas.upenn.edu)

**Jonathan P. Fiene**, Senior Lecturer and Director of Laboratory Programs  
Office: 220 Towne Phone: 215-573-6581 Email: [jfiene@seas.upenn.edu](mailto:jfiene@seas.upenn.edu)

**Andrew Jackson**, Professor of Practice  
Office: 222 Towne Phone: 215-746-4013 Email: [andjac@seas.upenn.edu](mailto:andjac@seas.upenn.edu)

**Robert L. Jeffcoat**, Adjunct Professor  
Office: 210 Towne Phone: 215-898-5791 Email: [rlj@seas.upenn.edu](mailto:rlj@seas.upenn.edu)

**Bruce Kothmann**, Senior Lecturer  
Office: 320 Towne Phone: 215-898-4817 Email: [kothmann@seas.upenn.edu](mailto:kothmann@seas.upenn.edu)

**Changchun Liu**, Research Assistant Professor  
Office: 216 Towne Phone: 215-898-1380 Email: [lchangc@seas.upenn.edu](mailto:lchangc@seas.upenn.edu)

**Patrick McGinnis**, Lecturer  
Office: 246 Towne Phone: 215-573-9928 Email: [pmcgin@seas.upenn.edu](mailto:pmcgin@seas.upenn.edu)

**Elliott Menschik**, Adjunct Associate Professor  
Office: 246 Towne Phone: 215-573-9928 Email: [menschik@seas.upenn.edu](mailto:menschik@seas.upenn.edu)

**Sarah Rottenberg**, Lecturer and Associate Director of the Integrated Product Design Program  
Office: 322 Towne Phone: 215-898-3108 Email: [srot@seas.upenn.edu](mailto:srot@seas.upenn.edu)



## **ADMINISTRATIVE STAFF**

As of 9/01/12

**Karen Brann**, Administrative Coordinator for the Engineering Entrepreneurship Program  
Office: 304 Towne Phone: 215-746-3686 Email: [brannk@seas.upenn.edu](mailto:brannk@seas.upenn.edu)

**Olivia R. Brubaker**, Associate Director of Undergraduate Programs  
Office: 229 Towne Phone: 215-898-4825 Email: [oliviarb@seas.upenn.edu](mailto:oliviarb@seas.upenn.edu)

**Maryeileen B. Griffith**, Associate Director of Graduate Programs  
Office: 229 Towne Phone: 215-898-2826 Email: [mebg@seas.upenn.edu](mailto:mebg@seas.upenn.edu)

**Desirae Johnson**, Administrative Assistant  
Office: 229 Towne Phone: 215-746-1818 Email: [desirae@seas.upenn.edu](mailto:desirae@seas.upenn.edu)

**Sue Waddington Pilder**, Office Manager and Assistant to the Chair  
Office: 229 Towne Phone: 215-898-2770 Email: [waddingt@seas.upenn.edu](mailto:waddingt@seas.upenn.edu)

## **TECHNICAL STAFF**

As of 9/01/12

**Terry Kientz**, Electronics and Laboratory Projects Engineer  
Office: 457 GRW Phone: 215-746-2861 Email: [tkientz@seas.upenn.edu](mailto:tkientz@seas.upenn.edu)

**Peter Rockett**, Instrumentation Technician  
Office: 166 Towne Phone: 215-898-2865 Email: [prockett@seas.upenn.edu](mailto:prockett@seas.upenn.edu)

**Peter Szczesniak**, Coordinator of Instructional Labs  
Office: 168B Towne Phone: 215-573-8150 Email: [peterszc@seas.upenn.edu](mailto:peterszc@seas.upenn.edu)

**Joe Valdez**, Journeyman Machinist  
Office: 191 Towne Phone: 215-898-4473 Email: [vjoseph@seas.upenn.edu](mailto:vjoseph@seas.upenn.edu)

## University of Pennsylvania's Code of Academic Integrity

([http://www.upenn.edu/academicintegrity/ai\\_codeofacademicintegrity.html](http://www.upenn.edu/academicintegrity/ai_codeofacademicintegrity.html))

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.