

## Elective Concentrations

The program in Mechanical Engineering is designed to appeal to students with a wide variety of interests and professional goals. By an appropriate choice of elective courses, students can develop a highly personalized curriculum.

Some suggested areas of concentration are biomedical engineering, design, energy and sustainability, intelligent mechanical systems, and computer-aided design/computer-aided manufacturing.

The *biomedical engineering* concentration is open to students interested in the biological and medical application of mechanical engineering procedures. Students may also want to consider the “pre-medical” concentration (below).

The *design* concentration focuses on product design supported by innovations, systematic design processes, and computational design methods while incorporating manufacturing and other life cycle considerations.

The *energy and sustainability* concentration emphasizes the mechanical aspects of energy conversion and management.

The *manufacturing* concentration is directed toward planning and selecting manufacturing methods, design for manufacture, computer-aided flexible automation and robotics, digital manufacturing, and increasing the efficiency and productivity of current and emerging manufacturing technologies.

The *MEMS/Nanotechnology* concentration focuses on the design and performance of nano and microscale devices, and materials behavior at these length-scales.

The *robotics* concentration focuses on robotics and the design of microprocessor-controlled electromechanical systems.

The *solid mechanics* concentration focuses on the study of stress and strain in solid bodies along with the application of computational methods for stress analysis.

The *thermo-fluids* concentration is appropriate for students with an interest in one of the wide array of technologies where fluid flow and heat transport are the dominant physical mechanisms.

The *pre-medical* concentration is open to students interested in obtaining an ME degree while also satisfying the requirements for admission to medical school.

It is possible that technical electives chosen according to the suggested concentrations below may not include two 300-level ME courses. This is acceptable provided that the technical electives satisfy the requirements of one of the areas of concentration.

## **Biomedical Engineering Concentration – 4 courses**

Choose one of the options below.

### **Required for all options:**

One course in mathematics or basic sciences.

#### ***Option 1: Biological Mechanics and Rehabilitation***

*Take both of these courses:*

BME 371 Mechanics of Biological Tissues  
BME 366 Biomechanics of Movement

*Choose one of these courses:*

ME 314\* Theory of Machines – Dynamics\*  
EECS 360\* Introduction to Feedback Systems\*  
ME 333 Mechatronics  
ME 433 Advanced Mechatronics  
ME 449 Robotic Manipulation  
ME 454 Opt. Control of Nonlinear Systems  
ME 495 Embedded Systems in Robotics

#### ***Option 2: Neural Engineering and Artificial Intelligence***

*Required basic math and science:*

BIO 302 Fundamentals of Neurobiology I

*Choose one of these courses:*

ME 314\* Theory of Machines - Dynamics\*  
EECS 360\* Introduction to Feedback Systems\* ME 333 Mechatronics  
ME 433 Advanced Mechatronics

*Choose one of these courses:*

EECS 325 Artificial Intelligence Programming  
EECS 332 Digital Image Analysis  
EECS 348 Intro to Artificial Intelligence  
EECS 349 Machine Learning  
EECS 495 Machine Learning & AI for Robots

*Choose one of these courses:*

BME 365 Ctrl of Human Limbs...  
BME 461 Computational Neuromechanics...  
BME 462 Sensory Acquisition  
BME 463 Systems Neuropathophysiology  
BME 465 Mdlng & Sim Human Movement  
BME 467 Biomedical Robotics  
BME 469 Neural Control & Mech of Mvment

#### ***Option 3: Biomaterials and regenerative medicine***

*Choose one of these three:*

BME 343 Biomaterials and Medical Devices  
MSCI 370 Biomaterials  
BME 344 Biol. Performance of Materials

*Choose one of these two:*

BME 346 Tissue Engineering  
BME 349 Bioregenerative Engineering

*Choose one from the following list:*

ChBE 361 Introduction to Polymers  
ChBE 379 Comp. Bio: Principles & Applications  
MSCI 318 Materials Selection  
MSCI 376 Nanomaterials

**Option 4: Imaging and biophotonics**

*Required:*

BME 325 Introduction to Medical Imaging

*Choose one of these two:*

BME 327 Magnetic Resonance Imaging

BME 333 Modern Opt. Micro. and Imaging

*Choose one from the following list:*

EECS 302 Prob. Systems and Random Signals

EECS 328 Numerical Methods for Engineers

EECS 332 Digital Image Analysis

EECS 360 Introduction to Feedback Systems

EECS 379 Lasers and Coherent Optics

EECS 382 Photonic Information Processing

EECS 395 Bioinformatics

**Option 5: Biological fluids and transport**

*Required:*

BME 350 Transport Fundamentals

*Choose two from the following list:*

ME 322\* Thermodynamics II\*

ME 373\*

Engr. Fluid Mechanics\*

ME 420 Micro & Nano Fluid Dynamics

ME 423 Intro to Comp. Fluid Dynamics

ME 424 Advanced Comp. Fluid Dynamics

ME 425 Introduction to Fluid Dynamics

ME 427 Viscous Fluid Mechanics

BME 450 Mass and Heat Transfer

BME 452 Transport Connective Tissues

\* If not taken to satisfy the Advanced Study requirement

### Design Concentration - 4 courses

**Required:** One course in mathematics or basic sciences

**Take any three from the following list:**

ME 333	Introduction to Mechatronics
ME 340-2	Computer Integrated Manufacturing
ME 341	Computational Methods for Engineering Design
ME 346	Introduction to Tribology
ME 359	Reliability Engineering
ME 365	Finite Elements for Stress Analysis (if not included as an ME Advanced Study course)
ME 366	Finite Elements for Design and Optimization
MSc 318	Materials Selection
IEMS 307	Quality Improvement by Experimental Design
DSGN 3xx	Any 300-level DSGN course ( <i>Note: Only one DSGN 3xx may count as a Tech Elective</i> )

### Energy and Sustainability Concentration - 4 courses

ISEN stands for the Institute for Sustainability and Energy at Northwestern

Note that ISEN 200-level courses cannot count as concentration courses, but may be taken as unrestricted electives.

**Required:** One course in mathematics or basic sciences

**Choose two from the following list:**

ME 322* OR ME 373*:	Thermodynamics II* OR Engineering Fluid Mechanics* (* whichever is not taken as an ME Advanced Study course)
ME 395 <sup>†</sup> :	Quantitative Methods in Life Cycle Analysis
ME 395 <sup>†</sup> /ISEN 395 <sup>†</sup> :	Thermal Energy Systems Design
ME 395 <sup>†</sup> :	Energy Systems
ME 495 <sup>†</sup> /ISEN 495 <sup>†</sup> :	Industrial Energy Management and Utilization
ME 495 <sup>†</sup> :	Sustainable Manufacturing Systems

**Choose one from the following list:**

ISEN 410:	Topics in Contemporary Energy and Climate Change
ISEN 430:	NUvention Energy
CHEM_ENG 365:	Sustainability, Technology and Society
CIV_ENV 368:	Sustainability: Issues and Actions Near and Far
MAT_SCI 381:	Materials for Energy-Efficient Technology

If the course in basic math and science is 300-level or above, then one of the three other courses may be 200 level. An interesting choice here may be CIV\_ENV 203: Energy and the Environment: The Automobile

<sup>†</sup> **Note:** The course numbers 395 and 495 are used as “generic” numbers for any course that does not yet have a permanent, unique number within the department. The fact that these particular 395 and 495 courses – with these particular titles – can count towards the “energy and sustainability concentration” should not be taken to indicate that all ME 395 courses can count towards the concentration.

### **Manufacturing Concentration - 4 courses**

**Required:** One course in mathematics or basic sciences

**Take one course from each of the following three groups:**

*Group 1:*

ME 340-2	Computer-Integrated Manufacturing: CAD/CAM
ME 340-3	Computer-Integrated Manufacturing: Automation

*Group 2:*

ME 346	Introduction to Tribology
EECS 390	Introduction to Robotics
MSc 317	Materials in Manufacturing
MSc 331	Soft materials
MSc 340	Ceramic Processing

*Group 3:*

ME 341	Computational Methods for Engineering Design
ME 366	Finite Elements in Design Optimization
EECS 360	Introduction to Feedback Systems
ME 359	Reliability Engineering
IEMS 305	Statistical Methods for Quality Improvement
IEMS 307	Quality Improvement by Experimental Design

### **MEMS/Nanotechnology Concentration – 4 courses**

**Required:** One course in mathematics or basic sciences

**Take three classes from the list below:**

ME 381 Introduction to MEMS  
ME 382 Experiments in Micro/Nano Science and Engineering  
ME 451 Micromachining  
EECS 388 Nanotechnology  
ME-CEE Finite Element Method  
ME 417 Multi-scale Modeling and Simulation in Solid Mechanics  
ME 418 Multi-scale Modeling and Simulation in Fluid Mechanics  
MAT\_SCI 376 Nanomaterials  
MAT\_SCI 455 Solid State Physics of Nanomaterials  
ME 420 Micro and Nano-Scale Fluid Dynamics  
ME 495 Computational Nanodynamics

## **Robotics Concentration – 4 courses**

**Required:** One course in mathematics or basic sciences

Some courses to consider that meet this requirement include:

BIOL_SCI 302	Fundamentals of Neurobiology I
BIOL_SCI 306	Fundamentals of Neurobiology II
BIOL_SCI 322	Systems and Computational Neuroscience
Any more advanced Neuroscience course (cannot be in the BME department, must be basic math/science)	
PSYCH 324	Perception
PSYCH 335	Decision Making
PSYCH 351	Advanced Statistics and Experimental Design
CSD 306	Psychoacoustics
CSD 310	Biological Foundations of Speech and Music
PHYSICS 352	Introduction to Computational Physics
PHYSICS 357	Optics Laboratory

**Required:**

ME 333	Introduction to Mechatronics
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**Take any two of these courses:**

*Courses that emphasize programming:*

EECS 205	Fundamentals of Computer System Software
EECS 211 A	Fundamentals of Computer Programming 1
EECS 211 B	Fundamentals of Computer Programming 2
EECS 230	Programming for Computer Engineers
EECS 336	Design and Analysis of Algorithms
EECS 457	Advanced Algorithms

*Courses that emphasize artificial intelligence:*

EECS 325	Artificial Intelligence Programming
EECS 332	Digital Image Analysis
EECS 348	Intro to Artificial Intelligence
EECS 349	Machine Learning
EECS 495	Machine Learning and Artificial Intelligence for Robotics

*Courses that emphasize neuroscience:*

*NOTE: Only 1 from this group can count as a Technical Elective towards the ME degree*

BME 365	Control of Human Limbs and Their Artificial Replacements
BME 461	Computational Neuromechanics and Neuroethology
BME 462	Sensory Acquisition
BME 463	Systems Neuropathophysiology
BME 465	Modeling and Simulation of Human Movement
BME 467	Biomedical Robotics
BME 469	Neural Control and Mechanics of Movement

*Courses that emphasize dynamics, mechatronics, robotics, and control:*

ME 314	Theory of Machines - Dynamics
ME 433	Advanced Mechatronics
ME 449	Robotic Manipulation
ME 454	Optimal Control of Nonlinear Systems
ME 495	Embedded Systems in Robotics
EECS 360	Introduction to Feedback Systems
EECS 374	Intro to Digital Control
EECS 390	Intro to Robotics
EECS 410	System Theory
EECS 495	Introduction to Nonlinear Control Theory

### **Solid Mechanics Concentration – 4 courses**

**Required:** One course in mathematics or basic sciences

**Take three classes from the list below:**

ME 362	Stress Analysis
CEE 319	Theory of Structures II (CEE 221 is a prerequisite)
CEE 320	Structural Analysis
ME 327 (CEE 327)	Finite Element Methods in Mechanics
ME 416	Computational Nanodynamics
ME 413	Experimental Solid Mechanics
ME 414	Mechanics of Composite Materials I
CEE 417	Mechanics of Continua I
ME 417	Multi-scale Modeling and Simulation in Solid Mechanics
ME426-I	Advanced Finite Element Methods

If the course in basic math and science is 300-level or above, then one of the three other courses may be 200 level. An interesting choice here may be ME 260, Mechanics of Sports

### **Thermo-fluids Concentration – 4 courses**

**Required:** One course in mathematics or basic sciences

**Take three classes from the list below:**

ME 322	Thermodynamics II	(if not taken as Advanced Study)
ME 373	Engineering Fluid Mechanics	(if not taken as Advanced Study)
ME 420	Micro & Nanoscale Fluid Dynamics	
ME 423	Introduction to Computational Fluid Dynamics	
ME 424	Advanced Computational Fluid Dynamics	
ME 425	Introduction to Fluid Dynamics	
ME 427	Viscous Fluid Mechanics	
BME 450	Mass and Heat Transfer	
BME 452	Transport through Connective Tissues	

## Pre-Medical Concentration

### Be sure to meet with a pre-med advisor early in your undergraduate career.

Note that the pre-med concentration requires students to use their “unrestricted electives” to complete the med school requirements for organic chemistry and biology.

In addition to the requirements listed below, med schools generally require:

- One year of General Chemistry with lab
- One year of Physics with lab (EA sequence replaces Physics 135-1. Should take Physics 135-2 and 135-3)
- One year of English/writing intensive (EDC counts for 1 quarter +2 courses from English or Comp Lit departments)
- Two or three quarters of Calculus

#### **Required:**

One year of Organic Chemistry with lab

This serves as a basic math and science tech elective and 2 unrestricted electives

#### **Do one of the following two options:**

*Option 1: (7 courses)*

BIOLSCI 215 – Genetics and Molecular Biology

BIOLSCI 216 – Cell Biology

BIOLSCI 217 - Physiology

BIOLSCI 218 – Biochemistry

BIOLSCI 220 – Genetic and Molecular Processes lab (0.3 credit)

BIOLSCI 221 – Cellular Processes lab (0.3 credit)

BIOLSCI 222 – Physiological Processes lab (0.3 credit)

Two 300-level ME tech electives

*Option 2: (7.6 courses)*

BIOLSCI 215 – Genetics and Molecular Biology

BIOLSCI 216 – Cell Biology

BIOLSCI 218 – Biochemistry

BIOLSCI 220 – Genetic and Molecular Processes lab (0.3 credit)

BIOLSCI 221 – Cellular Processes lab (0.3 credit)

BME 301, 302, 303 (all three courses are required by medical schools to replace BIO 217 and BIO 222)

One 300-level ME tech elective

The course schedule below assumes that a student begins with no A.P. credits. It shows one of several possible ways that a student could fulfil all degree requirements. If a student has some A.P. credits there is considerably more flexibility in the schedule. It is critical to meet with a pre-med advisor early to determine the best possible sequence of courses.

<b>Freshman</b>	<b>Sophomore</b>	<b>Junior</b>	<b>Senior</b>
<b>Fall</b>	<b>Fall</b>	<b>Fall</b>	<b>Fall</b>
EA1	EA4	BME 301 Physiology	ME 390 Dynamic Systems
General chemistry	ME 233 Electronics Design	Organic Chemistry	ME 224 Experimental Engr.
Calculus	Bio 215 + Bio lab	Civ-E 216 Mech. of Materials	ME 340-1 Manuf Processes
Humanities	Humanities	Humanities	Humanities
<b>Winter</b>	<b>Winter</b>	<b>Winter</b>	<b>Winter</b>
EA2	ME 202 Mechanics II	BME 302 Physiology	ME 373 Eng. Fluid Mech.
General chemistry	Mat Sci 201 Materials Science	Organic Chemistry	EECS 360 Feedback Systems
Calculus	Bio 216 + Bio lab	ME 377 heat transfer	Humanities
EDC	Physics 135-2	Humanities	ME Capstone
<b>Spring</b>	<b>Spring</b>	<b>Spring</b>	<b>Spring</b>
EA3	ME 240 Dsgn & Mfcturing	BME 303 Physiology	ME 362 Stress Analysis
General chemistry	ME 222 Thermo	Organic Chemistry	ME Tech Elective
Calculus	Bio 218	ME 315 Dsgn of Elements	Humanities
EDC	Physics 135-3	ME 241 Fluids	ME Capstone