**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 Mdling & 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 370* Thermodynamics II*
- 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 (Note: Only one DSGN 3xx may count as a Tech Elective)

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

†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

**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-CCE 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

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
- ME 426-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 370  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 fulfill 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.

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<td>Mat Sci 201 Materials Science</td>
<td>Organic Chemistry</td>
<td>EECS 360 Feedback Systems</td>
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<td>Calculus</td>
<td>Bio 216 + Bio lab</td>
<td>ME 377 heat transfer</td>
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