Engineering Science (ESG)

Major in Engineering Science
Department of Materials Science and Engineering, College of Engineering and Applied Sciences

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Minors of particular interest to students majoring in Engineering Science: Biomaterials (BES), Electronic, Optical, and Magnetic Materials (EOM), Manufacturing Engineering (MFE), Materials Science (ESM), Physical Metallurgy (PME)

Faculty

Christopher C. Berndt, Professor, Ph.D., Monash University: Condensed matter physics; nuclear waste management; probabilistic risk assessment.
Clive R. Clayton, Professor, Ph.D., University of Surrey: Structure and properties of materials; thin film processing.
Michael Dudley, Professor, Ph.D., University of Warwick: Synchrotron X-ray topography; defects in single crystals.
Richard J. Gambino, Professor and Principal Research Scientist, M.S., Polytechnic Institute of New York: Magnetic thin films; magneto-optical properties.
Dilip Gersappe, Assistant Professor, Ph.D., Northwestern University: Polymer science; computational methods in materials science.
Andrew Gouldstone, Assistant Professor, Ph.D., Massachusetts Institute of Technology: Properties of nanoscale coatings; thermal spray.
Pelagia Irene Gouma, Assistant Professor, Ph.D., University of Birmingham: Microstructural characterization of advanced materials; electron microscopy; microanalysis.
Gary P. Halada, Associate Professor, Ph.D., Stony Brook University: Surface analysis; synchrotron X-ray and infrared spectroscopies; environmental remediation; molecular spectroscopy.
Herbert Herman, Professor Emeritus, Ph.D., Northwestern University: Materials engineering; surface engineering; physical metallurgy.
Xian-rong Huang, Adjunct Professor, Ph.D., Nanjing University: Synchrotron x-ray topography.
Franco P. Jona, Professor Emeritus, Ph.D., Eidgenossische Technische Hochschule: Solid-state physics; modern materials.
Devinder Mahajan, Research Professor, Ph.D., University of British Columbia: Molecular and nano metal synthesis; liquid-phase catalysis.
Miriam Ralfovich, Professor, Ph.D., Stony Brook University: Polymer surfaces and interfaces.
J. Carlos Rojo, Assistant Professor, Ph.D., Universidad Autonoma de Madrid: Crystal growth of electronic and optoelectronic materials; numerical modeling of transport phenomena.
Sanjay Sampath, Professor, Ph.D., Stony Brook University: Thermal spray technology; tribology; functionally graded materials.

Steven Schwartz, Adjunct Professor, Ph.D., Stanford University: Materials and device characterization with secondary ion mass spectrometry.
Leslie L. Seigle, Professor Emeritus, D.Sc., Massachusetts Institute of Technology: Thermodynamics.
Jonathan C. Sokolow, Professor, Ph.D., Stony Brook University: Polymer surfaces and interfaces.
Albert Tobin, Adjunct Professor, Ph.D., Columbia University: Composites and ceramics.
David Welch, Adjunct Professor, Ph.D., University of Pennsylvania: Kinetics of diffusion; energetics; crystal lattice defects; radiation effects.
Henry White, Assistant Professor, Ph.D., Stony Brook University: Polymer nanocomposites; materials processing.

Affiliated Faculty
Benjamin Chu, Chemistry

Adjunct Faculty
Estimated number: 20

Teaching Assistants
Estimated number: 20

The Department of Materials Science and Engineering offers the Bachelor of Engineering degree program in Engineering Science and several interdisciplinary undergraduate programs in conjunction with other science and engineering departments on campus. The joint programs provide basic training for graduates to enter a wide range of industries or to proceed to graduate studies in engineering fields. They are aimed at the materials aspect of mechanical engineering, electrical engineering, physics, and chemistry. Engineering Science students can choose to specialize in biomedical engineering, mechanical and manufacturing engineering, electrical engineering, materials science and engineering, civil and environmental engineering, nanoscale engineering, or engineering research. Reflecting the breadth and variety of topics falling within the domain of engineering science, the Department also offers five minors that afford undergraduate students the opportunity to enhance their engineering or science studies with knowledge in a specific area. In addition to the minor in Materials Science, the Department offers minors in Biomaterials; Electronic, Optical, and Magnetic Materials; Manufacturing Engineering; and Physical Metallurgy. Each is detailed under a separate heading in the alphabetical listings of Approved Majors, Minors, and Programs.

The program mission is aimed towards providing an engineering education which thoroughly covers fundamental aspects of engineering design, physical and chemical sciences, mathematics, and materials science and engineering, while also providing flexibility so that students can create a program tailored to their particular academic and career interests in a traditional or emerging discipline. The program is designed to provide core competency and skills in communication, design, and research while preparing students to participate in a rapidly evolving high-technology environment.

The program goals—in alignment with the missions of professional engineering certification, professional engineering and research societies, and the Accreditation Board for Engineering and Technology—include educating graduates (1) who are prepared for entry into the engineering science professions; (2) who are committed to lifelong learning to remain proficient in state-of-the-art engineering throughout their careers; (3) who communicate effectively both orally and in writing; (4) who have a thorough grounding in mathematics, statistics, physics, and chemistry, as well as a firm foundation in mechanical engineering, electrical engineering, and materials science and engineering; (5) who are able to apply the fundamentals of engineering science to the design and analysis of existing systems and processes and who are capable of handling the open-ended types of design problems encountered in...
and medium-sized companies also rely on the expertise of materials scientists in design and manufacturing. In addition, some graduates apply their knowledge to patent law and consulting. About ten percent of the program’s graduates pursue advanced degrees in engineering research as well as in law, business, and medicine. The program in engineering science is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

Courses Offered in Engineering Science (ESG)
See the Course Descriptions listing in this Bulletin for complete information.
ESG 100 Introduction to Engineering Science
ESG 111 C Programming for Engineers
ESG 199 Introduction to Undergraduate Research
ESG 201-H Engineering Responses to Society
ESG 217 Engineering Science Design I
ESG 281 Engineering Introduction to the Solid State
ESG 300 Writing in Engineering Science
ESG 302 Thermodynamics of Materials
ESG 310 Research Methods for Engineers and Scientists
ESG 312 Engineering Laboratory
ESG 316 Engineering Science Design II: Methods
ESG 320 Sensor Materials and Devices
ESG 332 Materials Science I: Structure and Properties of Materials
ESG 333 Materials Science II: Electronic Properties
ESG 339 Thin Film Processing of Advanced Materials
ESG 440, 441 Engineering Science Design III, IV
ESG 487 Cooperative Research in Technological Solutions

Courses Offered in Materials Science (ESM)
See the Course Descriptions listing in this Bulletin for complete information.
ESM 221 Introduction to Chemistry of Solids
ESM 299 Directed Research in Materials Science
ESM 302 Introduction to the Crystalline State
ESM 309 Thermodynamics of Solids
ESM 325 Diffraction Techniques and Structure of Solids
ESM 334 Materials Engineering
ESM 335 Strength of Materials
ESM 336 Electronic Materials
ESM 350 Advanced Engineering Laboratory
ESM 353 Biomaterials: Manufacture, Properties, and Applications
ESM 355 Materials and Processes in Manufacturing Design
ESM 369 Polymers
ESM 450 Phase Changes and Mechanical Properties of Materials
ESM 475 Undergraduate Teaching Practicum
ESM 488 Cooperative Industrial Practice
ESM 499 in Materials Science

Acceptance into the Major in Engineering Science
Freshman and transfer applicants who have specified their interest in the Engineering Science major may be accepted directly into the major upon admission to the University. Students in good academic standing who were admitted to the University but not immediately accepted into the major may apply for acceptance in any semester, but priority for admission to the Engineering Science major is given to those students who have: 1) completed AMS 161 and PHY 132 or their equivalents, 2) earned a g.p.a. of 3.00 in all mathematics and physics courses with no more than one grade in the C range, and 3) received completed course evaluations for all transferred courses that are to be used to meet requirements for the major.
Requirements for the Major in Engineering Science (ESG)

The major in Engineering Science leads to the Bachelor of Engineering degree. Completion of the major requires approximately 110 credits.

A. Core

1. Mathematics
   AMS 151, 161; AMS 261 or MAT 203; AMS 361 or MAT 303
   Note: The following alternate calculus course sequences may be substituted for AMS 151, 161 in major requirements or prerequisites:
      MAT 125, 126, 127
      or MAT 131, 132
      or MAT 141, 142

2. Natural Sciences
   PHY 131/133 and 132/134; PHY 251 or ESG 281; CHE 198/199
   Notes:
   a. The physics course sequence PHY 125, 126, 127 or 141, 142 is acceptable in lieu of PHY 131/133, 132/134
   b. The chemistry course sequence CHE 131, 132, and 133 or CHE 141, 142, and 143 is acceptable in lieu of CHE 198 and 199.

3. Computer Science: ESG 111
   Note: MEC 111 or MEC 112 or CSE 114 or CSE 130 or ESE 124 may be substituted with permission of the department.

4. Engineering Science
   ESG 100; ESG 312; ESM 350; ESM 450; and the following nine courses:
   Materials Science and Engineering ESG 302, 332, 333, 339
   Electrical Engineering and Electronic Properties
   ESE 271, ESM 336
   Mechanical Engineering and Properties
   MEC 260, MEC 262, ESM 335

5. Engineering Synthesis and Design
   ESG 217, 316, 440, 441; ESM 355

B. Engineering Specialization and Technical Electives

The area of specialization, composed of five technical electives including at least two design-oriented courses, (or four electives plus the upper-division prerequisite in electrical engineering, ESE 372, or mechanical engineering, MEC 365) must be declared in writing by the end of the junior year. It is selected in consultation with a faculty advisor to ensure a cohesive course sequence with depth at the upper level.

The seven areas of specialization are biomedical engineering, civil and environmental engineering, electrical engineering, materials science and engineering, mechanical and manufacturing engineering, nanoscale engineering, and engineering research. The engineering research specialization requires: 1) a g.p.a. of at least 3.00, 2) a letter of intent from the student that indicates a particular area of research, and 3) permission of the undergraduate program director.

C. Upper-Division Writing Requirement: ESG 300 Writing in Engineering Science

All degree candidates must demonstrate skill in written English at a level acceptable for Engineering Science majors. The Engineering Science student must register for the writing course ESG 300 concurrently with ESG 316. The quality of writing in the technical reports submitted for ESG 316 is evaluated and students whose writing does not meet the required standard are referred for remedial help. Detailed guidelines are provided by the Department. If the standard of writing is judged acceptable, the student receives an S grade for ESG 300, thereby satisfying the requirement.

Courses with a # must be completed with a grade of C or higher.
Grading
All courses taken to satisfy Requirements A and B above must be taken for a letter grade. A grade of C or higher is required in the following courses (or their equivalents):

1. AMS 151, 161; PHY 131/133 and 132/134; ESG 217, 312, 339
2. Each of the five required technical electives offered by the college.

Areas of Specialization
Each area of specialization requires two design and three elective courses above those used toward Requirement A. Core. Other technical electives may be substituted only with the approval of the undergraduate program director.

Biomedical Engineering
Biomedical engineering is the application of various engineering disciplines to biomedical problems, requiring sound understanding of an engineering discipline coupled with principles of biology and medicine. Students utilize elective courses to learn the fundamentals of biology and bioengineering.

1. One of the following two-course design sequences must be completed.
   a. ESM 334 Materials Engineering
      ESM 335 Mechanical Properties of Materials
   b. MEC 310 Kinematics and Dynamics of Machinery
      MEC 410 Design of Machine Elements
   c. MEC 305 Heat and Mass Transfer
      MEC 364 Introduction to Fluid Mechanics

2. Three courses from the following:
   ESM 353 Biomaterials: Manufacture, Properties, and Applications
   BIO 150 The Living World
   BIO 203 Fundamentals of Biology: Cellular and Organ Physiology
   ESG 440/441 Engineering Science Design III/IV (See Note)

   Note: Three credits of research (ESM 499 or 488) may be used as a technical elective with permission of the undergraduate program director.

Civil and Environmental Engineering
Civil Engineering Track:
Civil and environmental engineering entails study, research, and design of infrastructure or processes responding to societal needs for sustainable development. The student completes one of two specializations. Each provides preparation for further study or employment in structural materials engineering, environmental remediation, or engineering involving design for environment (DFE).

1. Two required courses:
   a. ESM 334 Materials Engineering
   b. GEO/MAR 318 Engineering Geology and Coastal Processes
      or GEO 399 Structural Geology
      or MEC 364 Introduction to Fluid Mechanics

2. Three technical electives chosen from the following:
   GEO 315 Groundwater Hydrology
   MEC 305 Heat and Mass Transfer
   MEC 363 Mechanics of Solids
   MEC 406 Energy Management in Commercial Buildings
   MEC 455 Advanced Stress Analysis
   A third course from 1. above
   ESM 488 Co-operative Industrial Practice (3 cr.)
   or ESM 499 Research in Materials Science (3-4 cr.)
   or other departmental independent research with permission of the program director
   ESG 440, 441 Engineering Science Design III, IV (with permission of instructor and program director)

Environmental Engineering Track:
1. Two required courses:
   ESM 334 Materials Engineering
   CHE 312 Physical Chemistry

2. Three technical electives chosen from:
   ESG 320 Sensor Materials and Devices
   AMS 322 Groundwater Modeling
   GEO 316 Geochemistry of Surficial Processes
   GEO/MAR 318 Engineering Geology and Coastal Processes
   MAR 301 Environmental Microbiology
   MAR 336 Marine Pollution
   MAR 391 Environmental Policy
   ATM 397 Air Pollution and its Control
   CHE 361 Nuclear Chemistry
   CHE 362 Nuclear Chemistry Laboratory
   ESM 488 Co-operative Industrial Practice (3 cr.)
   or ESM 499 Research in Materials Science (3-4 cr.)
   or other departmental independent research with permission of the program director
   ESG 440, 441 Engineering Science Design III, IV (with permission of instructor and program director)

Electrical Engineering
This specialization is intended to provide a depth of understanding of electronic devices, electronic materials, and electrical and electronic system design built upon the broad engineering science curriculum.

1. One of the following two-course design sequences:
   a. ESE 218 Digital Systems Design
      and ESE 380 Microprocessors and Programmed Logic
   b. ESE 307 Modern Filter Design
      and ESE 312 Microwave Electronics

2. ESE 372 Electronics

3. Two courses chosen from the following:
   ESE 304 Applications of Operational Amplifiers
   ESE 305 Deterministic Signals and Systems
   ESE 306 Random Signals and Systems
   ESE 307 Modern Filter Design
   ESE 310 Electric Circuit Analysis II
   ESE 311 Analog Integrated Circuits
   ESE 315 Control Systems Design
   ESE 316 Digital Devices and Circuits
   ESE 319 Introduction to Electromagnetic Fields and Waves
   ESE 332 Semiconductor Device Characterization
   ESE 350 Electrical Power Systems
   ESE 352 Energy Conversion
   ESE 358 Computer Vision
   ESE 362 Optoelectronic Devices and Optical Imaging Techniques
   ESE 381 Embedded Microprocessor System Design II
   ESG 440/441 Engineering Science Design III/IV

Note: Three credits of research (ESM 499 or 488) may be used as a technical elective with permission of the undergraduate program director.
Materials Science and Engineering
This specialization provides the opportunity for in-depth study of the relationship between performance-properties-processing in materials engineering and its applications.
1. One of the following two-course design sequences:
   a. ESM 334 Materials Engineering and ESM 335 Mechanical Properties of Materials
   b. MEC 310 Kinematics and Dynamics of Machinery and MEC 410 Design of Machine Elements
   c. MEC 305 Heat and Mass Transfer and MEC 364 Introduction to Fluid Mechanics
   d. ESE 218 Digital Systems Design and ESE 380 Microprocessors and Programmed Logic I
   e. ESE 307 Modern Filter Design and ESE 312 Microwave Electronics
2. Three courses from the following:
   - ESM 302 Introduction to the Crystalline State
   - ESM 309 Thermodynamics of Solids
   - ESM 325 Diffraction Techniques and Structure of Solids
   - ESM 327 Solid Crystal Surfaces
   - ESM 333 Biomaterials
   - ESM 369 Polymers
   - ESM 475 Undergraduate Teaching Practicum
   - ESG 440/441 Engineering Science Design III/IV (See Note)
Note: Three credits of research (ESM 499 or 488) may be used as a technical elective with permission of the undergraduate program director.

Mechanical and Manufacturing Engineering
This specialization addresses the rapidly changing technology in the mechanical engineering and manufacturing industries that requires a highly educated workforce with knowledge of mechanical properties of materials, materials processing, design, thermodynamics, statistics, and analysis.
1. One of the following two-course design sequences:
   a. MEC 310 Kinematics and Dynamics of Machinery and MEC 410 Design of Machine Elements
   b. MEC 305 Heat and Mass Transfer and MEC 364 Introduction to Fluid Elements
   2. MEC 363 Mechanics of Solids
   3. Two courses from the following:
      - AMS 310 Survey of Probability and Statistics
      - MEC 325 Manufacturing Processes
      - MEC 364 Introduction to Fluid Mechanics
      - MEC 381 Transport and Fate of Pollutants
      - MEC 393 Engineering and Fluid Mechanics
      - MEC 398 Thermodynamics II
      - MEC 402 Mechanical Vibrations
      - MEC 411 System Dynamics and Control
      - MEC 420 Turbomachinery and Applications
      - MEC 422 Thermal System Design
      - MEC 455 Applied Stress Analysis
      - ESG 440/441 Engineering Science Design III/IV (See Note)
Note: Three credits of research (ESM 499 or 488) may be used as a technical elective with permission of the undergraduate program director.

Nanoscale Engineering
The creation of functional materials and devices which involves controllable processes and transformations at the scale of billionths of a meter promises to become a major focus of future efforts in both engineering and scientific research. With a thorough background in materials science, engineering design, and surface and molecular chemistry and devices, this specialization prepares students for graduate study, as well as professional positions in materials and process engineering and research and development.
1. Two required courses:
   a. ESM 334 Materials Engineering
   b. ESG 320 Sensor Materials and Devices
2. Three technical electives chosen from:
   - ESM 369 Polymers
   - CHE 301 Physical Chemistry I
   - CHE 302 Physical Chemistry II
   - CHE 321 Organic Chemistry I
   - CHE 322 Organic Chemistry II
   - CHE 345 Structure and Reactivity in Organic Chemistry
   - BME 381 Nanofabrication in Biomedical Applications
   - ESM 488 Cooperative Industrial Practice (3 cr.)
   - or ESM 499 Research in Materials Science (3-4 cr.)
   - or other departmental independent research with permission of the program director
   - ESG 440, 441 Engineering Science Design III, IV (with permission of instructor and program director)

Engineering Research
This specialization is intended for students who have the qualifications and motivation to pursue in-depth research and independent study over the course of several semesters in an area of engineering inquiry, usually in association with one or more of the Department's advanced materials research facilities. To qualify for this specialization, students must have a g.p.a. of at least 3.00 and the permission of the undergraduate program director and the instructor of ESG 440/441.
1. One of the following two-course design sequences
   a. ESM 334 Materials Engineering and ESM 335 Mechanical Properties of Materials
   b. MEC 310 Kinematics and Dynamics of Machinery and MEC 410 Design of Machine Elements
   c. MEC 305 Heat and Mass Transfer and MEC 364 Introduction to Fluid Elements
   d. ESE 218 Digital Systems Design and ESE 380 Microprocessors and Programmed Logic I
   e. ESE 307 Modern Filter Design and ESE 312 Microwave Electronics
2. The following five courses must be completed:
   - ESG 440/441 Engineering Science Design III/IV
   - a total of six credits of ESM 499, ESM 488, ESG 487 or ESM 475, and ESG 310 Research Methods
Note: ESG 440/441 Engineering Science Design III/IV counts for one technical elective with permission of the instructor and the undergraduate program director.
Engineering Chemistry
The Engineering Chemistry major combines work in the Department of Materials Science and Engineering and the Department of Chemistry and leads to the Bachelor of Science degree, awarded through the College of Arts and Sciences. See the major entry for additional information.

Physics of Materials
Physics majors may wish to pursue a career in engineering physics, particularly in the application of solid-state physics to materials science and engineering. After taking five courses in the Department of Materials Science and Engineering, the student may become eligible for the master's degree program. See the physics major entry for additional information.

Bachelor of Science Degree/Master of Science Degree Program
An engineering science, engineering chemistry, or physics student may apply at the end of the junior year for admission to this special program, which leads to a Bachelor of Engineering or Bachelor of Science degree at the end of the fourth year and a Master of Science degree at the end of the fifth year. In the senior year, a student in the program takes three credits of ESM 599 Research and three credits of an additional graduate course. In the fifth year the student takes 24 graduate credits, of which at least 15 credits are coursework and three credits are ESM 599. The advantages of this program over the regular M.S. program are that a student may start his or her M.S. thesis in the senior year, and that he or she needs only 24 credits in the fifth year as opposed to 30 credits for a regular M.S. student. For details of the M.S. degree requirements, see the Graduate Bulletin.