Mechanical Engineering

Program Description

The Mechanical Engineering Department offers a design-oriented, project-based undergraduate program that emphasizes fundamental engineering principles, with many courses providing hands-on and active learning experiences. Students receive a strong foundation in mechanical engineering disciplines and a working knowledge of modern engineering tools, e.g., design and manufacturing techniques. To explore the many opportunities as a mechanical engineer, students may choose a track which provides depth in specific areas, e.g., automotive, aerospace, biomechanics, energy and manufacturing, among others. With over 80% of our students participating in industry-sponsored internships or research with our faculty, our graduates are well prepared for a mechanical engineering career in a world of rapid technological change.

The Bachelor of Science in Mechanical Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org/, under the commission's General Criteria and Program Criteria for Mechanical Engineering.

Bachelor of Science in Mechanical Engineering

The Mechanical Engineering program intentionally embeds professional and technical skills, e.g., working on teams, engineering design, technical communication, and programming throughout the Mechanical Engineering curriculum. Our project-based design spine is bookended by the first-year experience in Introduction to Design (EDNS151) and our multidisciplinary capstone experience (EDNS 491 & 492) in the senior year. Following their first year at Mines, our students enter our project-based design spine in the middle years (sophomore and junior years):

- MEGN200 Introduction to ME: Programming & Hardware Interface. This course has students utilizing Arduinos while learning to program and breadboard to respond to an open-ended design problem.
- MEGN201 Introduction to ME: Design & Fabrication. In this course, students learn to design in SolidWorks, create technical drawings, use GD&T, and fabricate components in our machine shop with manual and CNC equipment.
- MEGN 300 Instrumentation and Automation: This course teaches our students to use more advanced instrumentation to collect and interpret real engineering data. Students use the LabVIEW programming language to design and control their devices and experiments.
- MEGN301 Mechanical Integration & Design. In this course students utilize the skills from the previous three courses as well as other ME courses to design, build and test their solution to an open-ended design project. This semester-long project immerses students in the design process and utilizes Scrum process to respond to project milestones.

This project-based experience teaches design methodology and stresses the creative aspects of the mechanical engineering profession. The courses help prepare students for open-ended, industry-based projects in the senior design experience.

Additionally, students complete an advanced mechanical engineering core that includes fluid mechanics, thermodynamics, dynamics, heat transfer, numerical methods, machine design, finite element analysis, and manufacturing processes. This engineering core is complemented by courses and electives in Culture and Society (CAS), which elaborate on the societal and economic impact of engineering solutions in our world. Students also take four advanced technical electives and three additional free electives to explore specific areas of interest. If students want to gain depth in a particular area on mechanical engineering, they can align their four ME electives in one of our eight tracks: Aerospace, Automotive, Automation and Controls, Biomechanics, Energy, Manufacturing, Materials, and Nuclear Energy.

There are plenty of opportunities outside of the curriculum for students to explore their passions. We have active Mines Maker Space, Robotics Club, and Formula SAE student groups among the over 300 student groups on campus, where students engage with the community, arts, and the outdoors.

Program Educational Objectives (Bachelor of Science in Mechanical Engineering)

The Mechanical Engineering program contributes to the educational objectives described in the Mines' Graduate Profile and the ABET accreditation criteria. Accordingly, the Mechanical Engineering program at Mines has established the following program educational objectives for the BS in Mechanical Engineering degree:

The Mechanical Engineering program prepares graduates within three to five years of completing their degree to:

- Apply their Mechanical Engineering education as active contributors to their professional community and society more broadly;
- Effectively communicate information and its practical and societal impact to a diverse and globally integrated society;
- Demonstrate their commitment to professional development and life-long learning through workforce readiness training, professional community involvement, and community outreach;
- Embody ethical, environmental and societal responsibility encompassing diversity, equity and inclusion in their professional activities.

Student Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Bachelor of Science in Mechanical Engineering Degree Requirements:

Freshman

Fall		**lec**	**lab**	**sem.hrs**
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
EDNS151	CORNERSTONE - DESIGN I			3.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0

Spring		**lec**	**lab**	**sem.hrs**
HASS200	GLOBAL STUDIES			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				15.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
CEEN241	STATICS			3.0
MTGN202	ENGINEERED MATERIALS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
MEGN200	INTRODUCTION TO MECHANICAL ENGINEERING: PROGRAMMING AND HARDWARE INTERFACE or 201			3.0
OR MEGN201	INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION			
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
MEGN212	INTRODUCTION TO SOLID MECHANICS			3.0
MEGN261	THERMODYNAMICS I			3.0
MEGN201	INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				18.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING			3.0
MEGN300	INSTRUMENTATION & AUTOMATION			3.0
MEGN315	DYNAMICS			3.0
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS			3.0
CAS	MID-LEVEL CAS			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MEGN301	MECHANICAL INTEGRATION & DESIGN			3.0
MEGN351	FLUID MECHANICS			3.0
MEGN381	MANUFACTURING PROCESSES			3.0
MEGN481	MACHINE DESIGN			3.0
MECH ELECT	Mechanical Engineering Elective*			3.0
				15.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
EDNS491	CAPSTONE DESIGN I			3.0
MEGN471	HEAT TRANSFER			3.0
MECH ELECT	Advanced Engineering Sciences Elective*			3.0
MECH ELECT	Mechanical Engineering Elective*			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
EDNS492	CAPSTONE DESIGN II			3.0
MECH ELECT	Mechanical Engineering Elective*			3.0
FREE	Free Elective			3.0
FREE	Free Elective			3.0

ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective	3.0
		15.0

Total Semester Hrs: 126.0

* Mechanical Engineering students are required to take three Mechanical Engineering elective courses. At least one of these courses must be from the Advanced Engineering Sciences list. The remaining must be from either the Advanced Engineering Sciences list or the Mechanical Engineering Electives list.

Advanced Engineering Sciences:

MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0

Mechanical Engineering Electives:

CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN433	MATRIX STRUCTURAL ANALYSIS	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
EDNS401	PROJECTS FOR PEOPLE	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
EENG417	MODERN CONTROL DESIGN	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN391	INTRODUCTION TO AUTOMOTIVE DESIGN	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN454	ORBITAL MECHANICS	3.0
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	3.0
MEGN486	LINEAR OPTIMIZATION	3.0
MEGN487	NONLINEAR OPTIMIZATION	3.0
MEGN488	INTEGER OPTIMIZATION	3.0
MEGN498	SPECIAL TOPICS IN MECHANICAL ENGINEERING (SPECIAL TOPICS)	1-6
MEGN5XX	ANY 500-LEVEL MEGN COURSE	3.0
MTGN211	STRUCTURE OF MATERIALS	3.0
MTGN442	ENGINEERING ALLOYS	3.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN464	FORGING AND FORMING	2.0
MTGN472	BIOMATERIALS I	3.0
MTGN475	METALLURGY OF WELDING	2.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN350	INTERMEDIATE MECHANICS	4.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
PHGN466	MODERN OPTICAL ENGINEERING	3.0
AMFG401	ADDITIVE MANUFACTURING	3.0
AMFG421	DESIGN FOR ADDITIVE MANUFACTURING	3.0
or AMFG521	DESIGN FOR ADDITIVE MANUFACTURING	
AMFG422	LEAN MANUFACTURING	3.0
AMFG4XX	Not Including 499	3.0
AMFG531	MATERIALS FOR ADDITIVE MANUFACTURING	3.0
AMFG511	DATA DRIVEN ADVANCED MANUFACTURING	3.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0
CSCI306	SOFTWARE ENGINEERING	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI437	INTRODUCTION TO COMPUTER VISION	3.0
CSCI442	OPERATING SYSTEMS	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
CSCI473	ROBOT PROGRAMMING AND PERCEPTION	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG310	INFORMATION SYSTEMS SCIENCE I	3.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0
MATH324	STATISTICAL MODELING	3.0
MATH332	LINEAR ALGEBRA	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MEGN4XX	Mechanical Tech Elective (not including 499 & required 400-level courses)	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
CSCI5XX	Non-project and research credit	
EENG5XX	Non-seminar and research credit	
FEGN5XX	Non-project and research credit	
MATH5XX	Non-project and research credit	
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
EBGN553	PROJECT MANAGEMENT	3.0
MNGN444	EXPLOSIVES ENGINEERING II	3.0
MTGN333	INTRODUCTION TO BLADESMITHING	3.0

INNO444	INNOV8X CREATE	3.0
INNO544	INNOV8X CREATE DSCI	1.0

Major GPA

During the 2016-2017 Academic Year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CEEN241
- EDNS491
- EDNS492
- MEGN100 through MEGN699 inclusive

Tracks for me undergraduate program

Tracks in Mechanical Engineering offer an opportunity for ME undergrads to explore various topics in mechanical engineering in more depth. Students gain depth in the areas by focusing their ME Electives on four courses prescribed in each track. Each proposed track is defined below with one course required in the Advanced Engineering Science Elective and three courses required from the ME Elective courses. Note that undergraduate students are not required to align with a track. Tracks are suggestions for students to gain advanced knowledge in a subdiscipline area and are "transcriptable."

Aerospace

Advanced Engineering Science Elective		
MEGN451	AERODYNAMICS	3.0
ME Elective (select 3 courses)		
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN452	INTRO TO SPACE EXPLORATION AND RESOURCES	3.0
MEGN453	AEROSPACE STRUCTURES	3.0
MEGN454	ORBITAL MECHANICS	3.0
MEGN455	AEROSPACE SYSTEMS ENGINEERING	3.0
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0

Automation & Controls

Advanced Engineering Science Elective		
MEGN416	ENGINEERING VIBRATION	3.0
ME Elective (select 3 courses)		
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG383	EMBEDDED SYSTEMS	4.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG411	DIGITAL SIGNAL PROCESSING	3.0
EENG417	MODERN CONTROL DESIGN	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN452	INTRO TO SPACE EXPLORATION AND RESOURCES	3.0
MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	3.0
MEGN540	MECHATRONICS	3.0

Automotive

Advanced Engineering Science Elective (select 1 course)		
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0
Must take both:		
MEGN391	INTRODUCTION TO AUTOMOTIVE DESIGN	3.0
MEGN417	VEHICLE DYNAMICS & POWERTRAIN SYSTEMS	3.0
ME Elective (select 1 course)		
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN465	ELECTRIC VEHICLE POWERTRAIN SYSTEMS	3.0

Biomechanics

Advanced Engineering Science Elective		
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
or MEGN416	ENGINEERING VIBRATION	
ME Elective (select 3 courses)		
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN536	COMPUTATIONAL BIOMECHANICS	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MTGN472	BIOMATERIALS I	3.0
FEGN525	ADVANCED FEA THEORY & PRACTICE	3.0

Energy

Advanced Engineering Science Elective		
MEGN461	THERMODYNAMICS II	3.0
ME Elective (select 3 courses)		
Choose 1 of the following:		
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN467	PRINCIPLES OF BUILDING SCIENCE	3.0
Choose 2 of the following courses or from above:		
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
MEGN560	DESIGN AND SIMULATION OF THERMAL SYSTEMS	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0

Manufacturing

Advanced Engineering Science Elective		
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
ME Elective (select 3 courses)		
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MTGN464	FORGING AND FORMING	2.0
AMFG401	ADDITIVE MANUFACTURING	3.0
AMFG422	LEAN MANUFACTURING	3.0

Materials

Advanced Engineering Science Elective		
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
ME Elective (select 3 courses)		
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN511	FATIGUE AND FRACTURE	3.0
MTGN211	STRUCTURE OF MATERIALS	3.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN464	FORGING AND FORMING	2.0
MTGN475	METALLURGY OF WELDING	2.0

Nuclear Energy

Advanced Engineering Science Elective		
MEGN461	THERMODYNAMICS II	3.0
ME Elective (select 3 courses)		
ENGY475	INTRODUCTION TO NUCLEAR ENGINEERING	3.0
NUGN506	NUCLEAR FUEL CYCLE	3.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
MEGN487	NONLINEAR OPTIMIZATION	3.0
MEGN488	INTEGER OPTIMIZATION	3.0
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
MTGN598	NUCLEAR MATERIALS POLITICS AND POLICY	3.0
NUGN598	MACHINE LEARNING IN NUCLEAR	3.0
SPRS598A	SPACE NUCLEAR POWER SYSTEMS	3.0

Combined Mechanical Engineering Baccalaureate and Masters Degrees

Mechanical Engineering offers a five year combined program in which students have the opportunity to obtain specific engineering skills supplemented with graduate coursework in mechanical engineering. Upon completion of the program, students receive two degrees, the Bachelor of Science in Mechanical Engineering and the Master of Science in Mechanical Engineering.

Admission into a graduate degree program as a Combined Undergraduate/Graduate degree student may occur as early as the first semester Junior year and *must be granted no later than the end of registration the last semester Senior year*. Students must meet minimum GPA admission requirements for the graduate degree.

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with “B-” or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

The Mechanical Engineering Graduate Bulletin provides detail into the graduate program and includes specific instructions regarding required and elective courses. Students may switch from the combined program, which includes a non-thesis Master of Science degree to a M.S. degree with a thesis option; however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

The Mines guidelines for Minor/ASI can be found in the Undergraduate Information section of the Mines Catalog.

Mechanical Engineering Areas of Special Interest (ASI) and Minor Programs

General Requirements

The Mechanical Engineering department offers minor and ASI programs. Students who elect an ASI or minor, must fulfill all prerequisite requirements for each course in a chosen sequence. Students in the sciences or mathematics must be prepared to meet prerequisite requirements in fundamental engineering and engineering science courses. Students in engineering disciplines are better positioned to meet the prerequisite requirements for courses in the minor and ASI Mechanical Engineering program. (See Minor/ASI section of the Bulletin for all requirements for a minor/ASI at CSM.)

For an Area of Special Interest in Mechanical Engineering, the student must complete the following 12 credits hours:

MEGN212	INTRODUCTION TO SOLID MECHANICS	3.0
MEGN261	THERMODYNAMICS I	3.0
MEGN315	DYNAMICS	3.0
MEGN351	FLUID MECHANICS	3.0

For a Minor in Mechanical Engineering, the student must complete a minimum of 18 credits from the following:

1. Required Courses (choose three, 9 credits)		
MEGN212	INTRODUCTION TO SOLID MECHANICS	3.0
MEGN261	THERMODYNAMICS I	3.0
MEGN315	DYNAMICS	3.0
MEGN351	FLUID MECHANICS	3.0
2. Tracks (choose one track):		
Robotics, Automation & Design Track (9 credits)		
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS	3.0
MEGN481	MACHINE DESIGN	3.0
MEGN381	MANUFACTURING PROCESSES	3.0
or MEGN441	INTRODUCTION TO ROBOTICS	

or MEGN416	ENGINEERING VIBRATION	
or MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	
Solid Materials Track (9 credits)		
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS	3.0
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
Thermal-Fluids Track (9 credits)		
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0
MEGN471	HEAT TRANSFER	3.0

Biomechanical Engineering Minor

General Requirements

To obtain a Biomechanical Engineering Minor, students must take at least 11.0 credits from the courses listed below. Fundamentals of Biology I (CBEN110) and Introduction to Biomechanical Engineering (MEGN330) are required (7.0 credits). Three more courses may be chosen from the proposed list of electives. The list of electives will be modified as new related courses become available.

Required Courses (7.0 credits)

CBEN110	FUNDAMENTALS OF BIOLOGY I	4.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0

Biomechanical Engineering Elective Courses

MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
or MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0
MEGN536	COMPUTATIONAL BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0
MEGN553	COMPUTATIONAL FLUID DYNAMICS	3.0
MEGNX98/X99	SPECIAL TOPICS *	3.0
MTGN472	BIOMATERIALS I	3.0
or MTGN572	BIOMATERIALS	
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN305	ANATOMY AND PHYSIOLOGY LAB	1.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN454	APPLIED BIOINFORMATICS	3.0
or CBEN554	APPLIED BIOINFORMATICS	
MATH431	MATHEMATICAL BIOLOGY	3.0
PHGN433	BIOPHYSICS	3.0
CBEN120	FUNDAMENTALS OF BIOLOGY II	4.0

* As the content of these courses varies, the course must be noted as relevant to the biomechanical engineering minor.

Minor and ASI in Additive Manufacturing

The interdisciplinary Additive Manufacturing program will prepare undergraduates to meet the challenges of careers in additive manufacturing. Undergraduate students have the following degree options:

- Area of Special Interest (12 credits)
  - Requirements: AMFG401 and 9 credits of electives (see Table 1)
- Minor (18 credits)
  - Requirements: AMFG401 and 15 credits of electives (see Table 1)

Table 1: Undergraduate elective courses, listed by specialty area (AMFG531, AMFG 511 and FEGN 526 require approval by appropriate program directors)

Additive Manufacturing of Structural Materials		
MEGN381	MANUFACTURING PROCESSES	3.0
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
AMFG421	DESIGN FOR ADDITIVE MANUFACTURING	3.0
AMFG531	MATERIALS FOR ADDITIVE MANUFACTURING	3.0
AMFG498	SPECIAL TOPICS IN ADVANCED MANUFACTURING	1-6
AMFG511	DATA DRIVEN ADVANCED MANUFACTURING	3.0
FEGN525	ADVANCED FEA THEORY & PRACTICE	3.0
FEGN526	STATIC AND DYNAMIC APPLICATIONS IN FEA	3.0

Aerospace Engineering Minor

The Aerospace Engineering minor includes six required courses listed below. Four of the courses currently exist in the mechanical engineering curriculum, and two are new courses. Courses in this minor, some developed in conjunction with industry, will help prepare Mines students for a career in aerospace industries.

SPRS498	INTRO TO SPACE EXPLORATION & RESOURCES	3.0
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN451	AERODYNAMICS	3.0
MEGN453	AEROSPACE STRUCTURES	3.0
MEGN454	ORBITAL MECHANICS	
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0
Total Semester Hrs		**15.0**

ASI in Aerospace Engineering

For an Area of Special Interest in Aerospace Engineering, the student must complete a minimum of 12 credits from the following:

MEGN451	FLUID MECHANICS II - AERODYNAMICS	3.0
MEGN471	HEAT TRANSFER	3.0
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN453	AEROSPACE STRUCTURES	3.0

Courses

MEGN200. INTRODUCTION TO MECHANICAL ENGINEERING: PROGRAMMING AND HARDWARE INTERFACE. 3.0 Semester Hrs.
This course introduces programming skills using Matlab as a means to collect and analyze data and utilizes Arduinos as a platform for prototyping circuits and designs. This course reinforces the engineering design process through problem definition and identifying constraints and criteria, encouraging multiple solutions, and introducing analysis in design through prototyping. Prerequisite: EDNS155 or HNRS105 or HNRS115 or HNRS198, CSCI101, CSCI102.
Course Learning Outcomes

- 1. Demonstrate programming logic through use of Matlab
- 2. Compose software programs (in Arduino) to solve engineering problems
- 3. Demonstrate hardware and software interface
- 4. Use Arduinos to produce a working prototype
- 5. Design simple circuits in use with Arduinos
- 6. Document problem definition, user needs, and project requirements through clear constraints and criteria
- 7. Create a working prototype and validate through testing
- 8. Compute the probability of a data set using MATLAB
- 9. Calculate statistics of a data set using MATLAB
- 10. Demonstrate technical writing and professional documentation of projects
- 11. Verbally communicate design solutions
- 12. Collaborate with team members to solve a design problem and produce a protoytpe.

MEGN201. INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION. 3.0 Semester Hrs.
This course reinforces basic drawing skills from Cornerstone Design, introduces SolidWorks tools to advance modeling skills, introduces machine shop skills (including safety and use of mill, lathe and CNC) and introduces GDnT practices important in fabrication and manufacturing, and prob-stats relevant to manufacturing. 3 hours lecture; 3 semester hours. Prerequisite: EDNS151 or EDNS155; HNRS105 or HNRS198A.
Course Learning Outcomes

- 1. Demonstrate basic drawing skills in orthographic views
- 2. Use SolidWorks to design an object and/or product
- 3. Demonstrate good GDnT practice in both documentation and prototypes
- 4. Employ general shop safety skills
- 5. Demonstrate manual use of mill - lathe - CNC
- 6. Apply statistical methods relative to manufacturing and GDnT
- 7. Design (prototype) a part for manufacturability (tolerances, assembly, clearances, etc.)
- 8. Demonstrate ability to implement quality control on designed parts
- 9. Communicate technical information through drawings and letter of intent
- 10. Collaborate with team members to produce a part/product.

MEGN212. INTRODUCTION TO SOLID MECHANICS. 3.0 Semester Hrs.
Equivalent with MEGN312,
This course introduces students to the principles of Solid Mechanics. Upon completion, students will be able to apply Solid Mechanics theories to analyze and design machine elements and structures using isotropic materials. The skills and knowledge learned in this course form the required foundation for Intro to Finite Element Analysis, Advanced Mechanics of Material, Machine Design and other advanced topics in engineering curricula. Practically, it enables students to solve real-world mechanical behavior problems that involve structural materials. This courses places an early focus on ensuring students have mastered the creation of free body diagrams given a mechanical system, then moves on to introduce and reinforce learning of stress and strain transformations, and failure theories. In practicing this knowledge, students will be able to analyze and design machine elements and structures of homogenous and heterogeneous geometries under axial, torsional, bending, transverse shear, internal pressure loads, and non-uniform loads. Students will be able to quantitatively communicate the outcomes. May not also receive credit for CEEN311. Prerequisite: CEEN241 (C- or better).
Course Learning Outcomes

- 1. Use free body diagrams in the analysis of structures
- 2. Apply principles of Solid Mechanics to the analysis of elastic structures under simple, combined, and thermal loading
- 3. Use Mohr’s circle and stress transformation equations
- 4. Use stress elements to show stress state at a point
- 5. Use failure theories to assess safety of design
- 6. Effectively communicate the outcomes of analysis and design problems

MEGN261. THERMODYNAMICS I. 3.0 Semester Hrs.
This course is a comprehensive treatment of thermodynamics from a mechanical engineering point of view. Topics include: Thermodynamic properties of substances inclusive of phase diagrams, equations of state, internal energy, enthalpy, entropy, and ideal gases; principles of conservation of mass and energy for steady-state and transient analyses; First and Second Law of thermodynamics, heat engines, and thermodynamic efficiencies; Application of fundamental principles with an emphasis on refrigeration and power cycles. May not also receive credit for CBEN210. Prerequisite: MATH213 (C- or better).
Course Learning Outcomes

- 1. Identify the boundary of a system by drawing a control surface and label the transfer of mass and energy across the control surface for a given process.
- 2. Apply balance equations (mass, energy, and entropy) to analyze steady and unsteady processes, relating a system’s inputs and outputs (heat, work, and mass transfer) and material properties (temperature, pressure, etc.) with one another.
- 3. Determine the properties of pure substances using equations of state, property tables, software tools, or thermodynamic surfaces, choosing an appropriate method.
- 4. Use the 1st and 2nd law of thermodynamics to identify possible and impossible processes.
- 5. Apply the concept of isentropic efficiency to compare actual and ideal devices.
- 6. Use the concepts of thermal efficiency and coefficient of performance to analyze the performance of power cycles (power plants and internal combustion engines), and assess the performance by comparing to other cycles, to theoretical limits, and to practical material and economic limitations.
- 7. Represent thermodynamic processes in multiple formats, by drawing process schematics, drawing thermodynamic property (P-

v and T-s) diagrams, applying balance equations, and writing for diverse audiences (science and non-science).
- 8. Design and analyze thermodynamic systems (cycles and other devices) to meet heating, cooling, and/or power needs for a specified application.

MEGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN300. INSTRUMENTATION & AUTOMATION. 3.0 Semester Hrs.
This course will explore instrumentation and automation of electro-mechanical systems. Students will utilize LabView and electro-mechanical instrumentation to solve advanced engineering problems. Class activities and projects will highlight the utility of LabView for real-time instrumentation and control. Prerequisite: MEGN200 (C- or better). Corequisite: MEGN201.
Course Learning Outcomes

- 1. Recognize the strengths and limitations of the software and hardware platforms for instrumentation, data collection and analysis
- 2. Create customized instrumentation systems and user interfaces
- 3. Explore software architectures for instrumentation and control
- 4. Explore various sensor and actuator technologies
- 5. Apply probability and statistics in large data sets
- 6. Design an instrumentation system for a specific application
- 7. Communicate testing procedures and analysis in a technical report
- 8. Discuss hardware platforms for embedded industrial instrumentation and control, including NI myRIO and CompactRIO

MEGN301. MECHANICAL INTEGRATION & DESIGN. 3.0 Semester Hrs.
Students will utilize the engineering design process and knowledge in systems level design to produce a mechanical product/process. Students will reverse engineer a product/process to emphasize the steps in the design process. Students will select a longer course project, which is intended to reinforce engineering skills from other courses. The project topics would parallel one of the four research disciplines in ME, and students would be able to choose a topic pathway that emphasizes opportunities for mechanical engineering graduates. Prerequisite: MEGN200 (C- or better), MEGN201 (C- or better), MEGN300 (C- or better). Corequisite: MEGN 381.
Course Learning Outcomes

- 1. apply the engineering design process, from recognition of client needs to release of a fully-tested mechanical/electromechanical product
- 2. apply a systems-level approach in the design of a product
- 3. incorporate regulatory requirements and/or standards and additional realistic constraints pertinent to mechanical/electromechanical devices, products or systems into the design process
- 4. apply technical knowledge in engineering, mathematics, and the sciences to design and benchmark mechanical/electromechanical products
- 5. use modern engineering software tools in mechanical product design (e.g. Matlab, SolidWorks, or LabView)
- 6. demonstrate use of statistics and probability in the analysis of test results
- 7. professionally document and communicate design efforts

MEGN315. DYNAMICS. 3.0 Semester Hrs.
This course will cover particle kinematics (including 2-D motion in x-y coordinates, normal-tangential coordinates, & polar coordinates), rigid body kinematics (Including relative velocities and accelerations), rigid body kinetics (including the equation of motion, work and energy, linear impulse-momentum, & angular momentum), and introduction to vibrations. Prerequisite: CEEN241 (C- or better) and MATH225 (C- or better). MATH225.
Course Learning Outcomes

- 1. Understand the basic principles of particle dynamics.
- 2. Understand the basic principles of planar rigid body dynamics.
- 3. Demonstrate the ability to apply the principles of dynamics to solve basic engineering problems with analytic and numerical techniques.

MEGN324. INTRODUCTION TO FINITE ELEMENT ANALYSIS. 3.0 Semester Hrs.
Equivalent with MEGN424,
This course aims to teach basic proficiency with Finite Element Analysis (FEA), which is the most widely used computer aided engineering tool in industry, academia, and government. Fundamentals of FEA theory are introduced, but the majority of the course is spent learning practical skills with commercial FEA software. Students will work interactively with the instructor and with their peers to complete hands-on FEA examples based primarily on problems in structural mechanics. Applications of FEA for heat conduction, natural frequency analysis, and design optimization are covered briefly. The course will conclude with a mini project on which students use FEA skills for engineering analysis and design. The importance of verification and validation (V&V) for critical evaluation of FEA predictions is emphasized, and students will make frequent use of statics and solid mechanics principles to corroborate their FEA results. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).
Course Learning Outcomes

- Understand the basic concepts of th e global stiffness force-displacement matrix equations in the displacement finite element method.
- Use a commercial finite element software package (SW Simulation), associated CAD modeling software (SolidWorks) and an engineering math softwa re (MATH CAD) to perform engineering analysis.
- Apply classical engineering methods such as statics and mechanics of materials to check whether the results of a finite element analysis are sensible.
- Apply finite element analysis in the engineering design process. For example, design a simple truss structure and perform finite element analyses to determine the dimensions of the structural members based on specified design constraints.
- Write clear and concise technical memoranda and reports describing the results of an engineering analysis and their use in an engineering design if appropriate.

MEGN330. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3.0 Semester Hrs.
The application of mechanical engineering principles and techniques to the human body presents many unique challenges. The discipline of Biomedical Engineering (more specifically, Biomechanical Engineering) has evolved over the past 50 years to address these challenges. Biomechanical Engineering includes such areas as biomechanics, biomaterials, bioinstrumentation, medical imaging, and rehabilitation. This course is intended to provide an introduction to, and overview of, Biomechanical Engineering and to prepare the student for more advanced Biomechanical coursework. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply various mechanical engineering principles to the human body. Prerequisite: CEEN241.
Course Learning Outcomes

- Understand the basic concepts in applying material learned in other Mechanical Engineering classes (statics, mechanics of materials) to analysis of the human body

MEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I,II,S) Supervised, full-time engineering- related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EGGN340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a 'Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements' form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor.Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00.

MEGN351. FLUID MECHANICS. 3.0 Semester Hrs.
This course will cover principles of fluid properties, fluid statics, control-volume analysis, Bernoulli equation, differential analysis and Navier-Stokes equations, dimensional analysis, internal flow, external flow, open-channel flow, and turbomachinery. May not also receive credit for CEEN310 or PEGN251. Prerequisite: CEEN241 with a grade of C- or better or MNGN317 with a grade of C- or better.
Course Learning Outcomes

- Solve mass conservation, momentum, and energy equations for steady-state fluid-flow systems (control-volume analyses).
- Apply differential conservation-of-mass and linear-momentum equations and material derivatives to the solution of flow problems (differential analysis).
- Establish non-dimensional groupings of fluid properties, and apply them in the design of experiments that scale between models and prototypes (dimensional analysis).
- Model fully developed laminar and turbulent pipe flow systems (internal flow).
- Develop the relationships for lift and drag on bodies moving through a fluid (external flow).
- Convey understanding of course materials through homework assignments and exams.
- Distinguish what physical aspects are most critical and have greatest impact on a given problem and design.
- Establish an intuition of fluid behavior, analyze its effects in a given problem, and apply your knowledge to propose design solutions.

MEGN381. MANUFACTURING PROCESSES. 3.0 Semester Hrs.
Equivalent with MEGN380,
Manufacturing Processes is a survey course, that introduces a wide variety of traditional and advanced manufacturing processes with emphasis on process selection and hands-on experiences. Students are expected to have basic knowledge in material science, basic machining and GD&T before entering the class. Throughout the course students analyze the relationships between material properties, process variables and product functionality. Students design and evaluate processes for identifying value while eliminating waste using learned skill-sets including lean methodologies, six-sigma and statistical process control. Quality, cost, standards and ethics related to manufacturing are discussed throughout the semester. Prerequisite: MEGN201 with a grade of C- or better and MTGN202. MEGN212.
Course Learning Outcomes

- Understand basic manufacturing processes and how they apply to designed parts, materials and assemblies
- Be able to use design for manufacturability concepts when designing parts

MEGN385. INTRODUCTION TO CNC AND CAM PROGRAMMING. 1.0 Semester Hr.
This course will guide students through the process of machining parts on a 3-axis CNC (computer numeric-controlled) milling machine. The code for the CNCs will be generated with a CAM (computer aided-machining) program. We will machine parts with multiple setups and discuss strategies for complicated parts. Prerequisite: MEGN 201.
Course Learning Outcomes

- 1. Utilize CAM programming to create the machine code for CNCs.
- 2. Apply milling tool datasheets to optimize the machining performance.
- 3. Select tooling based on the characteristics of specific tools and material setups for creating unique part features.
- 4. Evaluate and select tool operations for efficient material removal and precisely detailed part features.
- 5. Set up and operate 3 axis vertical CNC milling machines
- 6. Design parts for CNC manufacturability
- 7. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

MEGN391. INTRODUCTION TO AUTOMOTIVE DESIGN. 3.0 Semester Hrs.
Automotive engineering involves the design and implementation of complex systems. This course introduces students to the workings of the automotive industry, including its history, future, and the stakeholders that determine its direction. The course also covers the major vehicle subsystems and their functionality, interfaces, components, and recent advancements. Students will apply theoretical and practical systems engineering principles to perform a design of a vehicle subsystem to gain perspective of how the automotive design process is executed and how it fits into the larger scope of the automotive industry. Prerequisite: MEGN200 with of grade C- or better.

Course Learning Outcomes

- 1. Work on a successful design team to create a design for a significant mechanical, electrical, structural, or industrial system.
- 2. Identify performance, manufacturing, and safety standards, on system and subsystem levels, that will lead to design success.
- 3. Create design concepts and alternatives, and apply selection criteria.
- 4. Identify and solve design-related engineering analysis problems.
- 5. Conduct cost and safety analyses.
- 6. Communicate a design process and its results by written report, technical illustration, and oral presentation.
- 7. Manage a design project, including: making and keeping schedules; allocating and utilizing resources; specifying and acquiring components; meeting budgets and deadlines.

MEGN398. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN408. INTRODUCTION TO SPACE EXPLORATION. 3.0 Semester Hrs.

Overview of extraterrestrial applications of science and engineering by covering all facets of human and robotic space exploration, including its history, current status, and future opportunities in the aerospace and planetary science fields. Subtopics include: the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), current research, missions, and projects, the international and commercial perspectives, and discussion of potential career opportunities. This seminar style class is taught by CSM faculty, engineers and scientists from space agencies and research organizations, aerospace industry experts, and visionaries and entrepreneurs of the private space commerce sector.

MEGN412. ADVANCED MECHANICS OF MATERIALS. 3.0 Semester Hrs.

This Advanced Mechanics of Materials course builds upon the learning outcomes of the pre-requisite Mechanics of Materials (Solid Mechanics) course to teach students the fundamentals of elastic deformations. Introduction to energy methods, strain and stress transformations, constitutive relations for isotropic and orthotropic materials, and to fracture mechanics is realized through theory development, application examples, and numerical solutions. Knowledge from this course will enable students to work on variety of engineering applications in Mechanical, Materials, Aerospace, Civil and related engineering fields. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).

Course Learning Outcomes

- 1. Define, and apply, displacement-strain relationships. Calculate principal strains, maximum shear strain in 2D and 3D.
- 2. Use gauges and rosettes for strain measurements.
- 3. Find stresses at a point, principal stresses and max shear stress.
- 4. Define, and apply, the generalized form of Hooke’s Law for isotropic materials.
- 5. Define, and apply, the generalized form of Hooke’s Law for orthotropic materials.
- 6. Apply theories of failure for ductile and brittle materials.
- 7. Use energy methods to compute strain energy, determine the effect of impact loading, determine displacements due to single or multiple loads, and solve statically indeterminate problems.
- 8. Define crack modes and stress intensity factor. Estimate stresses in the “near-field”.
- 9. Apply plastics zone size correction to the crack length.
- 10. Explain, and apply, the design philosophy given by the relationship between material property (fracture toughness), design stress, allowable flow size or NDT flaw detection.
- 11. Estimate fatigue life of cracked and un-cracked components.

MEGN414. MECHANICS OF COMPOSITE MATERIALS. 3.0 Semester Hrs.

Introductory course on the mechanics of fiber-reinforced composite materials. The focus of the course is on the determination of stress and strain in a fiber-reinforced composite material with an emphasis on analysis, design, failure by strength-based criteria, and fracture of composites. Anisotropic materials are discussed from a general perspective then the theory is specialized to the analysis of fiber-reinforced materials. Both thermal and hygroscopic sources of strain are introduced. Classical laminated plate theory is next developed, and design of laminated composite structures is introduced. The analysis of helically reinforced composite tubes concludes the course. Prerequisite: MEGN212 (C- or better).

Course Learning Outcomes

- 1. Apply concepts of the mechanics of composite materials to the analysis of fiber-reinforced lamina
- 2. Use transformation equations to analyze fiber-reinforced lamina with arbitrary fiber orientation
- 3. Predict overall elastic properties of a fiber-reinforced lamina from micromechanics models
- 4. Choose and apply an appropriate failure criterion to assess safety of fiber-reinforced lamina
- 5. Apply classical laminated plate theory to calculate stresses in laminated composites
- 6. Design a laminated plate structure given mechanical and thermal loads
- 7. Determine the stress state in helically reinforced composite tubes

MEGN416. ENGINEERING VIBRATION. 3.0 Semester Hrs.

This course introduces linear theory of mechanical vibrations as applied to single- and multi-degree-of-freedom systems. Specifically, students learn to analyze and measure free and forced vibrations of spring-mass-damper systems in response to different types of loading including harmonic, impulse, and general transient loading. Force balance and energy methods are introduced as means to create models of vibrating mechanical components. Ultimately, students learn to apply these theories to design vibration isolators and dampers for machines subject to translational and rotational vibrations, including machines with rotating unbalances and two or more vibrating masses. Prerequisite: MEGN315 (C- or better).

Course Learning Outcomes

- ability to apply knowledge of mathematics, science, and engineering
- ability to identify, formulate, and solve engineering problems

MEGN417. VEHICLE DYNAMICS & POWERTRAIN SYSTEMS. 3.0 Semester Hrs.
This course offers an introduction to automotive engineering with a focus on vehicle design, suspension, powertrain and aerodynamics. The course is designed to introduce students to both theoretical and practical concepts of vehicle design with applications in increasing fuel efficiency and vehicle performance. The study of automotive engineering is of increasing importance as new technologies emerge and advances continue to be made to existing designs to create the ultimate driving experience; while having minimal impact on the environment by reducing tailpipe gas emissions, noise pollution, and waste material during manufacturing of new vehicles. Prerequisite: MEGN315, MEGN324, MEGN261.
Course Learning Outcomes

- Students will use fundamental lateral and longitudinal dynamic equations to design the proper suspension setup for various road and racing scenarios
- Students will be able to identify key components of a vehicle's suspension and powertrain system and describe their respective function to the performance of the vehicle
- Students will perform relevant calculations and numerical modeling related to vehicle design and handling characteristics (e.g. roll, over/under-steer)
- Students will solve basic engine performance calculations related to power and torque and determine which final drive ratio is adequate for certain racing applications

MEGN430. MUSCULOSKELETAL BIOMECHANICS. 3.0 Semester Hrs.
This course is intended to provide mechanical engineering students with a second course in musculoskeletal biomechanics. At the end of the semester, students should have in-depth knowledge and understanding necessary to apply mechanical engineering principles such as statics, dynamics, and mechanics of materials to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. 3 hours lecture; 3 semester hours. Prerequisite: MEGN212 OR CEEN311; MEGN315; MEGN330 (C- or better).
Course Learning Outcomes

- Understand advanced concepts in applying material learned in other Mechanical Engineering classes (statics, mechanics of materials) to analysis of the human body

MEGN435. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties, interactions with the environment, and computational optimization to construct detailed computer models and simulations of human movement. Prerequisite: MEGN315 with a grade C- or better, MEGN330 with grade of C- or better.

MEGN441. INTRODUCTION TO ROBOTICS. 3.0 Semester Hrs.
Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. EENG307 is recommended to be completed before this course. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: (MEGN200 or CSCI261 or CSCI200) and (EENG281 or EENG282 or PHGN215).
Course Learning Outcomes

- To be completed at a later time (course coordinator on leave)

MEGN451. AERODYNAMICS. 3.0 Semester Hrs.
Review of elementary fluid mechanics and engineering; Two-dimensional external flows, boundary layers, and flow separation; Gas dynamics and compressible flow: Isentropic flow, normal and oblique shocks, rocket propulsion, Prandtl-Meyer expansion fans; Application of computational fluid dynamics. Prerequisite: MEGN351(C- or better).
Course Learning Outcomes

- • Apply control-volume conservation-of-mass, linear-momentum, angular-momentum and energy equations to the solution of flow problems.
- • Apply differential conservation-of-mass and linear-momentum equations and to the solution of flow problems.
- • Understand development and analysis of boundary layers.
- • Comprehend analysis of compressible and supersonic flows, including shock waves.
- • Understand theory and application of turbomachinery.

MEGN452. INTRO TO SPACE EXPLORATION AND RESOURCES. 3.0 Semester Hrs.
Overview of human and robotic space exploration, including its history, current status, and future opportunities. Course topics cover the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), the aerospace industry, space commerce and law, and the international space activity. Emphasis is placed on the field of space resources, including their identification, extraction, and utilization to enable future space exploration and the new space economy.

MEGN453. AEROSPACE STRUCTURES. 3.0 Semester Hrs.
This course covers advanced mechanics of materials relevant to the analysis and design of aerospace structures. Focused topics include multiaxial stress states, nonsymmetric loading, composites, airframe loads, and shear flow emphasizing lightweight, often thin-walled structures common in aerospace applications. Other advanced topics will be introduced, time permitting. Prerequisite: MEGN212.
Course Learning Outcomes

- Understand physical & mathematical relationship(s) between displacement, stress, and strain.
- Apply concepts of compatibility, equilibrium, and constitutive relations on geometries preva- lent in aerospace structural analysis.
- Distinguish appropriate failure criteria and assumptions under various airframe loading con- ditions.
- Solve basic boundary value problems on plane stress, plane strain, torsion, beam bending, and shear flow for thin-walled structures.
- Gain team experience through a design/build/test project that utilizes concepts learned in the course

MEGN454. ORBITAL MECHANICS. 3.0 Semester Hrs.
Orbital Mechanics introduces students to the dynamics that govern motion of bodies in space and the utilization of these dynamics in spacecraft orbit and trajectory design. This course develops the mathematical foundation of propagating, describing, and manipulating the motion of a spacecraft in orbit. Throughout the semester students will script their own (basic) universe simulators to examine the various forces and geometries in orbit. Prerequisite: MEGN315.
Course Learning Outcomes

- 1. Calculate the position of a body (satellite) under Keplerian dynamics as a function of time.
- 2. Interpret the state and orbit type of a body (satellite) in an elliptical orbit using classic orbital elements.
- 3. Implement a state propagator for a body (satellite) in an elliptical orbit in Keplerian dynamics and under common perturbation models.
- 4. Calculate the impulsive delta-V maneuvers required to manipulate a body's (satellite) orbit state in common transfers

MEGN455. AEROSPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
An introduction to aerospace systems engineering. This course is designed for students to explore both theoretical and practical systems engineering concepts and knowledge using examples drawn from the aerospace and defense industries. Starting with the systems engineering v model, students will gain hands on experience working with modern Model Based Systems Engineering (MBSE) software and develop systems engineering deliverables such as Concepts of Operations (ConOps) documents as part of a semester long project. Prerequisite: Best taken just before Senior Design or as a co-req with Senior Design I.
Course Learning Outcomes

- 1. Students will be able to describe the most important systems engineering standards and best practices as well as newly emerging approaches using the systems engineering V-model.
- 2. Students will be able to write and decompose multi-level system requirements
- 3. Students will learn applied model-based systems engineering and demonstrate their understanding using an industry standard Model Based System Engineering (MBSE) software
- 4. Students will develop and demonstrate applied model-based engineering, through development of support document for their semester long project
- 5. Students will demonstrate their understanding of system mission and operating environments through the develop of a concept of operations (ConOps) document
- 6. Students will be able to identify system risks and opportunities and appropriately rank and defend their approach
- 7. Students will demonstrate their understanding of interfaces, constraints, and system specifications/figures of merit/technical performance metrics/measure of performance through the drafting of an Interface Control Document (ICD)
- 8. Students will visually communicate their understanding of project execution via the develop of a system engineering management plan (SEMP)
- 9. Students will demonstrate understanding of the value of appropriate test procedures and test plans through the development of a project test plan
- 10. Students will be able to differentiate between validation and verification in the systems engineering context

MEGN456. SPACE OPERATIONS AND MISSION DESIGN. 3.0 Semester Hrs.
Space Operations and Mission Design (SOMD) is a course for upper level undergraduate and graduate students at Mines who are interested in expanding their knowledge of astrodynamics, spacecraft and space mission design, project management, and systems engineering.
Upon leaving the course, students will have a head start on potential internships/careers in the aerospace industry armed with key vocabulary and terms, experience with industry relevant software and tools, and core skills and knowledge gained through practice addressing real-world problems in the space domain.
Course Learning Outcomes

- Students shall develop and defend their mission risk/opportunity assessment, applying risk matrices and mitigation plans as tools.
- Students shall collaboratively define, design, and plan a simulated mission considering stakeholders, associated space laws/regulations, and resource management.
- Students shall develop and assess technical resource budgets. Examples include: mass, power, thermal, telecommunications, and data volume.
- Students shall apply appropriate terminology associated with space flight operations
- Students shall execute space mission planning principles such as: Orbit determination, Orbital maneuvering, Launch windows, Orbital rendezvous, and Proximity operations
- Students shall analyze orbital motion by visualizing from both inertial and relative perspectives
- Students shall synthesize the effects of launch, orbital maneuvers, rendezvous, and proximity operations on space situational awareness and space mission design and operations

MEGN461. THERMODYNAMICS II. 3.0 Semester Hrs.
This course extends the subject matter of Thermodynamics I (MEGN261) to include the study of exergy, ideal gas mixture properties, psychrometrics and humid air processes, chemical reactions, and the 1st, 2nd and 3rd Laws of Thermodynamics as applied to reacting systems. Chemical equilibrium of multi-component systems, and simultaneous chemical reactions of real combustion and reaction processes are studied. Concepts of the above are explored through the analysis of advanced thermodynamic systems. 3 hours lecture; 3 semester hours. Prerequisite: MEGN351 (C- or better), MEGN261 (C- or better).
Course Learning Outcomes

- Ability to solve and analyze physical processes that include: Exergy (2nd Law) analysis of energy systems • Mixtures of ideals gases • Psychrometrics including mass and energy balances of humid air processes • Chemical reactions, combustion, and fuel/air stoichiometry • Phase and chemical equilibrium • Simultaneous reactions and Ionization • Thermodynamics of compressible flow in nozzles including shock • Advanced thermodynamic cycles including cascaded and absorption refrigeration systems, cryogenics, and gas turbine and combined cycles.

MEGN465. ELECTRIC VEHICLE POWERTRAIN SYSTEMS. 3.0 Semester Hrs.
In the fast-evolving world of sustainable transportation, it is essential for engineers in the automotive industry to understand energy conversion,

storage, utilization, and optimization of vehicle powertrains. Electric Vehicle Powertrain Systems (EVPS) is designed to provide students with a comprehensive understanding of the essential powertrain components in battery-electric vehicles (BEVs) including motors, controllers, and battery packs. Through a combination of theoretical modeling and hands-on projects, students will gain knowledge and skills in powertrain system design to achieve vehicle objectives, encompassing energy analysis, power requirements, and efficiency considerations. The course will also explore the state-of-the-art in safety measures, management strategies, control systems, charging/balancing techniques, and State of Charge (SOC)/State of Health (SOH) estimation for EV battery packs. Prerequisite: MEGN300 or EEGN 282.
Course Learning Outcomes

- 1. Articulate the functions and interrelationships of the core powertrain components in electric vehicles, including the motor, controller, and battery pack
- 2. Design a vehicle powertrain architecture and select powertrain components that meet the overarching goals of an electric vehicle, incorporating top-level requirements such as energy use, power output, and efficiency optimization
- 3. Explain the operating principles and fundamental characteristics of Li-ion batteries using underlying electrochemical processes and implement them in an equivalent circuit battery cell model
- 4. Apply experimental methods used to characterize the performance of Li-ion cells in automotive applications, while elucidating the principles and significance of these techniques in assessing battery behavior and performance.
- 5. Critically assess and compare the state of the art in safety protocols, management strategies, control systems, and charging/balancing techniques for battery packs in electric vehicle powertrain systems.
- 6. Devise a functional design for a battery pack tailored to the specific requirements and constraints of a full-size electric vehicle, integrating considerations such as energy storage capacity, thermal management, safety measures, and space utilization

MEGN466. INTRODUCTION TO INTERNAL COMBUSTION ENGINES. 3.0 Semester Hrs.
Introduction to Internal Combustion Engines (ICEs); with a specific focus on Compression Ignition (CI) and Spark Ignition (SI) reciprocating engines. This is an applied thermo science course designed to introduce students to the fundamentals of both 4-stroke and 2-stroke reciprocating engines ranging in size from model airplane engines to large cargo ship engines. Course is designed as a one-semester course for students without prior experience with IC engines, however, the course will also include advanced engine technologies designed to deliver more horsepower, utilize less fuel, and meet stringent emission regulations. Discussion of advancements in alternative fueled engines will be covered as well. This course also includes an engine laboratory designed to provide hands-on experience and provide further insight into the material covered in the lectures. Prerequisite: MEGN351 with a grade of C- or better, MEGN261 with a grade of C- or better. Co-requisite: MEGN471.
Course Learning Outcomes

- ABET j and k outcomes will be measured through homework assignments and projects.

MEGN467. PRINCIPLES OF BUILDING SCIENCE. 3.0 Semester Hrs.
This course covers the fundamentals of building heating, ventilation, and air conditioning (HVAC) systems and the use of numerical heat and moisture transfer models to analyze or design different building envelope and HVAC systems. Prerequisite: MEGN351 with a grade of C- or better, MEGN261 with a grade of C- or better.
Course Learning Outcomes

- 1. Understand and apply fundamental principles to HVAC design
- 2. Describe components in HVAC systems
- 3. Understand how building HVAC loads are calculated and calculate building HVAC loads
- 4. Conduct building energy analyses using computer simulation tools

MEGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN469,MTGN469,
Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisite: MEGN261 with a grade of C- or better or CBEN357 with a grade of C- or better.

MEGN471. HEAT TRANSFER. 3.0 Semester Hrs.
Engineering approach to conduction, convection, and radiation, including steadystate conduction, nonsteady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. 3 hours lecture; 3 semester hours. Prerequisite: MEGN351 (C- or better), MEGN261 (C- or better), and MATH307.
Course Learning Outcomes

- Outcome 1: Ability to analyze and design heat transfer processes and systems
- Outcome 2: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

MEGN475. INTRODUCTION TO NUCLEAR ENGINEERING. 3.0 Semester Hrs.
An overview of major concepts and themes of nuclear engineering founded on the fundamental properties of the neutron, and emphasizing the nuclear physics bases of nuclear reactor design and its relationship to nuclear engineering problems. Major topics that introduce fundamental concepts in nuclear engineering include the physics and chemistry of radioactive decay, radiation detection, neutron physics, heat transfer in nuclear reactors, and health physics. Nuclear engineering topics relevant to current events are also introduced including nuclear weapons, nuclear proliferation, and nuclear medicine. Prerequisite: MATH225, PHGN200.
Course Learning Outcomes

- 1) Apply concepts of radioactivity to solve problems
- 2) Relate neutron production and consumption to aspects of the lifecycle of the nuclear fuel and nuclear power production
- 3) Apply the basics of nuclear reactor physics and heat transfer to reactor design and operation
- 4) Understand the biological effects of radiation and use basic radiation shielding equations

MEGN479. OPTIMIZATION MODELS IN MANUFACTURING. 3.0 Semester Hrs.
We address the mathematical formulation and solution of optimization models relevant in manufacturing operations. The types of deterministic

optimization models examined include: (i) network models; (ii) linear programs; (iii) integer programs; and, (iv) nonlinear programs. Application areas include scheduling, blending, equipment replacement, logistics and transportation, among other topics. Students learn not only how to mathematically formulate the models, but also how to solve them with a state-of-the-art modeling language (Ampl) and appropriate solver (e.g., Cplex or Minos). Algorithms for each problem class will be briefly discussed.

MEGN481. MACHINE DESIGN. 3.0 Semester Hrs.
In this course, students develop their knowledge of machine components and materials for the purpose of effective and efficient mechanical design. Emphasis is placed on developing analytical methods and tools that aid the decision making process. The course focuses on determination of stress, strain, and deflection for static, static multiaxial, impact, dynamic, and dynamic multiaxial loading. Students will learn about fatigue failure in mechanical design and calculate how long mechanical components are expected to last. Specific machine components covered include shafts, springs, gears, fasteners, and bearings. 3 hours lecture; 3 semester hours. Prerequisite: MEGN315 (C- or better) or PHGN350 (C- or better), and MEGN324 (C- or better).
Course Learning Outcomes

- 1. Use a systematic approach for solving design problems
- 2. Be able to design new systems for current technology

MEGN485. MANUFACTURING OPTIMIZATION WITH NETWORK MODELS. 3.0 Semester Hrs.
Equivalent with EBGN456,
We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. 3 hours lecture; 3 semester hours. Prerequisite: MATH111, MATH 112.
Course Learning Outcomes

- Mathematically formulate optimization models to reflect real-world manufacturing settings.
- Study algorithms and software to solve associated optimization problems.
- Use skills from other engineering courses to identify manufacutring problems and set them up as optimization models.

MEGN486. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
This course addresses the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. Prerequisite: MATH332 or EBGN509.
Course Learning Outcomes

- 1. Understand how to formulate linear optimization models.
- 2. Understand how to solve linear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear optimization models and how this affects their ability to be solved.
- 4. Understand sensitivity and post-optimality analysis.

MEGN487. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN587,
This course addresses both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111.
Course Learning Outcomes

- 1. Understand how to formulate nonlinear optimization models.
- 2. Understand how to solve nonlinear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying nonlinear optimization models and how this affects their ability to be solved.

MEGN488. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN588,
This course addresses the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MATH111, MATH112.
Course Learning Outcomes

- 1. Understand how to formulate linear-integer optimization models.
- 2. Understand how to solve linear-integer optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear-integer optimization models and how this affects their ability to be solved.
- 4. Understand decomposition techniques to aid in solution.

MEGN498. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Note that MEGN499 does not count as an

MEGN Teachnical Elective, though the course does count as a Free Elective. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

Professor and Department Head

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Emeriti Professors

Joan Gosink

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Graham G.W. Mustoe

Terry E. Parker

Emeriti Associate Professors

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