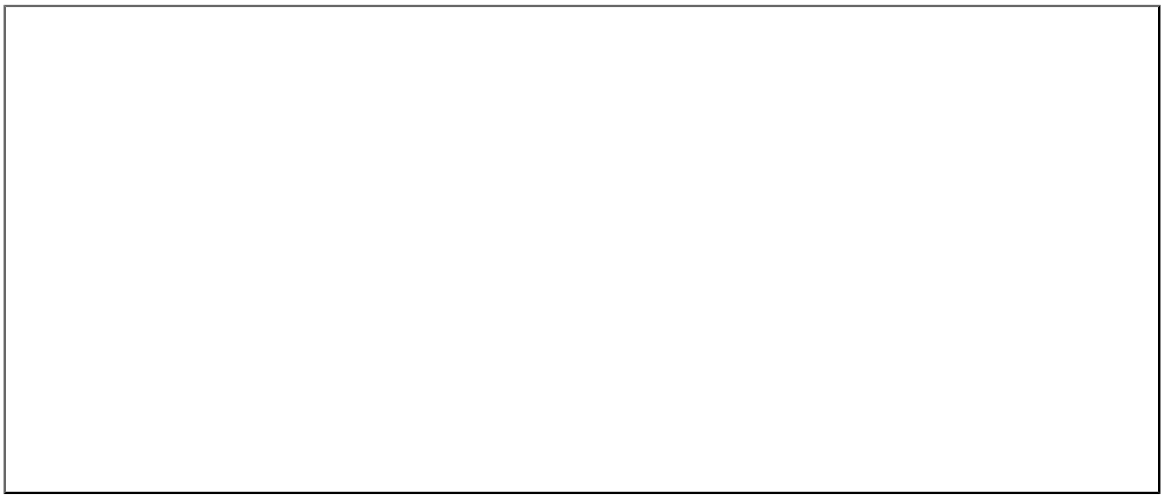
Rose-Hulman Institute of Technology Course Catalog



- MA386 Statistical Programming
- MA384 Data Mining
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undergraduate technical education. The five course curriculum (20 credits) introduces students to the fundamentals of an entrepreneurial mindset.

Two required courses (total of 8 credits):

EMGT 330 - Introduction to Engineering Management
EMGT 432 or 532 - Technical Entrepreneurship

Three elective courses (total of 12 credits) from the following:

EMGT 100 - Introduction to Entrepreneurship
EMGT 175 - Personal Finance
EMGT 520 - Accounting for Technical Managers
EMGT 521 - Financial Management in a Technical Envoronment
EMGT 523 - Marketing in New Product Development
EMGT 526 - Innovation Management & Forecasting
EMGT 527 - Project Management
ECON S151 - Introduction to Microeconomics
ECON S152 - Introduction to Macroeconomics
ECON S352 - Corporate Finance
ECON S350 - International Trade & Globalization
ECON S355 - International Finance
PHIL H202 - Business and Engineering Ethics

Note: There are no prerequisites for the EMGT courses, but the HSSA courses have prerequisites. Please refer to the course catalog.

With approval from the Department Head of Engineering Management, course substitutions may be considered to align with a student's professional aspirations. No more than one course may be transferred in to count toward the minor.

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence and machine learning. Imaging is used across all areas of science and engineering, for example, in the vision systems in self-driving cars, in robotics, and in automating medical diagnostics, even to the point of detecting a person's pulse from a video of their face.

Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. The minor requires 24 credits (6 courses): three required courses and three imaging electives from the list below. Since imaging is a multidisciplinary minor, at least 12 of the 24 credits must be courses that are not named required courses for the student's major.

Students choose a track to pursue. Each track allows the student to gain depth in a different area. Each has its own required courses and suggested electives (although any electives from the list below are acceptable).

Track 1: Medical Imaging
Expected majors: **BE, EE, Csrh16aH, O, EEP] TJ 1 0 0 -1 0 634's pulse fromHSSA coursep21 pR**

Required courses: **ECE582/PH537, CSSE463, MA490 (Deep Learning)**
Plus three electives from the **Imaging Electives** list below.
Recommended electives: **MA490 (Machine Learning), ECE480/OE437, CSSE461**

Track 3: **Real-time Rendering**
Expected majors: **CS/SE, ECE, MA**
Required courses: **CSSE351, CSSE451, MA323**
Plus three electives from the **Imaging Electives** list below.
Recommended electives: **MA371 or MA373, ECE480, CSSE/MA325, IA142 or IA244**

Track 4: **Acquisition of Images**
Expected majors: **ECE, PHOE, BE**
Required courses: **ECE480/OE437, PH405, OE295**
Plus three electives from the **Imaging Electives** list below.
Recommended electives: **OE480, OE392**

Track 5: **Creative Imaging**
Expected majors: **CS/SE, ECE, MA**
Required courses: **IA142, ECE480, CSSE/MA325**
Plus three electives from the **Imaging Electives** list below.
Recommended electives: **CSSE351, MA323, IA244**

Imaging Electives (choose any 12 credits that are not required for your track, as long as at least 12 of the 24 credits for the minor are not named, required courses for your major)

BE340 Biomedical Signal Processing or ECE380 Discrete-Time Signal Processing (only one can be taken as a minor elective)

BE435/OE435 Biomedical Optics

CSSE325/MA325 Fractals and Chaotic Dynamical Systems

CSSE351 Computer Graphics,

CSSE413 Artificial Intelligence

CSSE451 Advanced Computer Graphic

CSSE461 Computer Vision

CSSE463 Image Recognition

ECE480/OE437 Introduction to Image Processing

ECE580 Digital Signal Processing

ECE582/PH537 Advanced Image Processing

ECE584/BE541 Medical Imaging Systems

IA142 Drawing or IA244 Design and Color (only one can be taken as a minor elective)

MA323 Geometric Modeling

MA371 Linear Algebra or MA373 Applied Linear Algebra

MA439 Mathematical Methods of Image Processing

MA490 Deep Learning

MA490 Machine Learning

OE295 Photonics Devices and Systems OE392 Linear Optical Systems.

OE480 Optical System Design

OE592 Fourier Optics and Applications

PH405 Semiconductor Materials and Applications

PH538 Introduction to Neural Networks

Any special topics course or independent study in any major that involves imaging (must be approved by the Imaging Program Director.

MINOR IN INTERNET OF THINGS

Internet of Things (IoT) is a broad field of study which has applications across many disciplines. The technologies which enable IoT range from material science for sensors and energy harvesting applications to complex real-time analysis of large, aggregated data sets. This encompasses fields such as embedded system design, sensor design, energy harvesting and storage, networking, wireless communications, distributed systems, databases, edge and cloud computing, machine learning, data analysis, security, and privacy. The applications for Internet of Things include agricultural monitoring and automation, infrastructure monitoring, traffic monitoring and control, environmental monitoring, smart retail logistics, industrial monitoring and automation, smart homes, smart cities, mobile health, and intelligent environments.

Students in any degree program are eligible for the minor. To earn the Minor in Internet of Things, a student must complete a minimum of 24 credit hours in a course plan approved by an internet of things minor advisor.

Advisors: Dr. Chris Miller, Dr. Yosi Shibberu, Dr. Sid Stamm, Dr. Alan Chiu, Dr. David Henthorn, Dr. Mark Spencer

Required Courses

MDS 210 Introduction to Internet of Things (4 cr)

Plus 20 additional credit hours in a plan approved by one of the minor advisors in collaboration with the student to suit their particular interests and field of study. To provide students with a breadth of knowledge in the Internet of Things, this plan should include courses in the areas of: hardware design of end devices, including sensors and actuation; software design and data analysis; and networks and security. The guidelines are designed to be flexible to accommodate students from any major; the tables below provide some examples of courses which fit these categorizations. No more than 8 credit hours from a named required course for the student's major may be counted toward the minor requirements.

A sampling of courses which could be used to satisfy minor requirements

Hardware design

CHE310	Numerical Methods for Chemical Engineers	4
MA335 / CSSE335	Introduction to Parallel Computing (cross-listed)	4
MA384 / CSSE384	Data Mining (cross-listed)	4
ME447	Visualizing Data	4

Networks and security

Course	Description	Hours
CSSE132	Introduction to Computer Systems	4
CSSE432	Computer Networks	4
CSSE442	Computer Security	4
ECE312	Communication Networks	4
MA479 / CSSE479	Cryptography	4

As is the case with any minor at Rose-Hulman, the Institute does not guarantee to any student that the courses that fulfill the minor will be available in all quarters to suit the student's plan of study.

MINOR IN MATERIALS SCIENCE AND ENGINEERING

Materials science and engineering is a broad field of study. As the name implies, it encompasses foundational knowledge from the sciences (e.g. physics, chemistry, and biology) and it includes the engineering application of this knowledge to create new materials and to select, modify, and combine existing materials in novel and useful ways. Developments in materials science and engineering are critical to success in many areas of science and technology. The relationship between the structure, processing, and properties of materials is central to the discipline, and therefore the courses in this minor teach students about one or more of these areas. Rose-Hulman Institute of Technology offers a Minor in Materials Science and Engineering to recognize students who have gained experience in these areas while at Rose-Hulman. Students in any degree program are eligible for this minor, except students working toward the minor in Solid State Physics/Materials Science.

To earn the Minor in Materials Science and Engineering, a student must complete a minimum of 24 credit hours according to the guidelines below. These guidelines are designed to be flexible in order to accommodate students from different majors across the Institute. Consequently, some courses are listed in multiple categories even though any given course may only be counted once toward the minor. In some cases, a prerequisite may be waived if the instructor determines that the student has sufficient background knowledge from previous coursework taken in other departments. Prerequisites are included for reference but are subject to change; the course catalog contains the official prerequisites.

(1) One of the following introductory courses (or course sequences):

Course	Description	Hours	Prerequisites
BE 233	Biomaterials &	3	None
and BE 315	Biomedical Engineering Lab	2	BE 232, BE 233, BE 314*
CHE 315	Materials Science and Engineering	4	CHEM 115

ME 328	Materials Engineering	4	CHEM 111

**corequisite*

(2) A total of 20 additional credit hours from one or both of the following categories. Any course required for a student's major (excluding elective courses required for the major, and other exceptions as specified in the footnotes) does not count toward these 20 credit hours, nor does any course taken to satisfy requirement (1) above.

(i) A minimum of 12 credit hours of the following elective courses:

**BE

Course	Description	Hours	Prerequisites
BE 233	Biomaterials	3	
BE 560	Tissue-Biomaterial Interactions [1]	4	BE 361**
BE 597 & Other BE	Special Topics, requires approval of minor advisor		

	405, EP 410, and ME 416)		
Course	**Description**	**Hours**	**Prerequisites**
ECE 419	Advanced MEMS: Modeling & Packaging (cross-listed with CHE 419 and EP 411)	4	EP 410 or equivalent course
ECE 543	Electromagnetic Metamaterials	4	ECE 341
EP 280	Intro to Nano-Engineering	4	
EP 330	Material Failure	4	PH 112
EP 380	Nanotechnology, Entrepreneurship & Ethics	4	EP 280
ME 328	Materials Engineering [3]	4	CHEM 111
ME 414	Materials Selection in Mechanical Design [1]	4	EM 204
ME 423	Fatigue [1]	4	EM 204
ME 424	Mechanics of Composites [1]	4	EM 204 and ME 328
ME 428	Materials Research and Instrumentation [1]	4	CHEM 111 and Jr Standing
ME 517	Mechanics of Metal Forming [1]	4	EM 204
ME 497 & Other ME	Special Topics, requires approval of minor advisor.[1]		May count more than one relevant course toward minor
OE 360	Optical Materials	4	PH 255 and PH 316
PH 255	Foundations of Modern Physics	4	PH 113 and MA 211*
PH 405	Semiconductor Materials & Applications	4	PH 113 or PH 255 or PH 265
PH 407	Solid State Physics	4	PH 255 or PH 265

PH 440	X-rays and Crystalline Materials	4	PH 255 or PH 265
PH 113 OR EM 204	Physics III [4] Or Statics & Mechanics of Materials II [4]	4	PH 112 and MA 112 and MA 113* Or EM 121
With permission of a minor advisor, up to four credit hours of independent study and/or self-directed research		≤ 4	

[1] *Tentative plans for electives can be found on department-specific my.rose-hulman.edu pages.*

[2] *CE majors may count CE 320 toward fulfillment of the minor even though it is in category (2)*

[3] *CHE 315 and ME 328 cannot both count toward fulfillment of the minor*

[4] *PH 113 or EM 204 cannot be taken as a terminal course. A materials elective that requires*
PH 113 or EM 204 as a prerequisite must also be taken in fulfillment of minor requirements.

corequisite course; **consent of instructor; * or concurrent registration*

(ii) A maximum of 8 credit hours of the following elective courses that focus on mechanics of materials:

Course	Description	Hours	Prerequisites
EM 505	Theory of Elasticity	4	EM 203 or EM 204
ME 422	Finite Elements for Engineering Applications	4	EM 204
ME 522	Advanced Finite Element Analysis	4	ME 422

A student interested in pursuing a Minor in Materials Science and Engineering should consult with one of the following minor advisors: Dr. Matthew Riley (Department of Mechanical Engineering), Dr. Emma Dosmar (Department of Biology and Biomedical Engineering), or Dr. Marissa Tousley (Department of Chemical Engineering). Successful completion of this minor will be indicated on the student's transcript.

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics, mechatronics, and assistive technologies. Rose-Hulman Institute of Technology offers a

[4]Note, the list of additional required ME courses appears to be 1 course longer than other tracks, but ME students are required to take either Control Systems (ME406) or Vibration Analysis (EM406) already, so the requirement to take ME406 should not cause the ME track to be any longer.

(5) ENGD majors - Additional required courses:

- ES214 Mechanical Systems 2
- ES205 Analysis and Design of Engineering Systems
- ME406 Controls
- ME430 Mechatronic Systems
- MDS410/20/30 Multidisciplinary Capstone - ENGD majors should select projects that build on robotics learning from earlier courses.

(6) For majors not listed above - Additional required courses:

- CSSE220 Object-Oriented Software Development
- ME430 Mechatronic Systems
- BE350 or ECE 320 or ME 406 [or a Controls course from any major] [5]
- 4 credits of Robo Electives (see list below)

[5] For BE majors, a controls course will fill an area requirement. So, much like the ME track, the requirement to have a controls course should not cause this track to be longer for BE majors than tracks for other majors.

Robotics Electives

Students choose Robotics Electives from the list below subject to the restrictions that a student's Robotics Elective courses(s) cannot be any course listed above as an additional required course for the student's major, and cannot be a course listed as a named requirement for the student's major.

- BE350 Biocontrol Systems
- BE520 Brain Machine Interfaces
- BE543 Neuroprosthetics
- CSSE286 Machine Learning
- CSSE413 Artificial Intelligence
- CSSE480 Web App Frameworks with AppEngine
- CSSE483 Android Application Development
- CSSE484 iOS Application Development
- CSSE461 Computer Vision
- CSSE463 Image Recognition
- CSSE490 Swarm Intelligence
- CSSE290/490 Teamwork and Robotics
- ECE320 Linear Controls
- ECE300 Continuous Time Signals and Systems
- ECE414 Wireless Systems
- ECE420 Discrete-time Control Systems
- ECE480/PH437 Image Processing
- ECE483 Digital Signal Processing System Design

- ECE497 Advanced Mobile Robotics
- ECE582/OE537 Advanced Image Processing
- ECE583 Pattern Recognition
- PHYC S410 Computational Psychology
- MA415 Macihne Learning
- MA416 Deep Learning
- ME304 Introduction to the Design of Mechanisms
- ME404 Advanced Design of Mechanisms
- ME406 Control Systems
- ME445 Robot Dynamics and Control
- ME497 Design of Mechanisms I
- ME497 Design of MEchanisms II
- ME497 Industrial Controls
- ME497 Three Dimensional Dynamics
- ME506 Advanced Control Sys
- ME518 Advanced Kinematics
- EM502 Advanced Dynamics
- EP408 Microsensors
- CSSE490/ME497/ECE497 Robotics Studio
- Independent study courses in robotics k5,ics k5,uir 0 -1 sensors

- EMGT447 Six Sigma in Practice

Supporting Coursework (8 credit hours):

Two courses selected from the following list. Courses not on this list may count towards the minor if approved by the minor advisor.

- EMGT330 Introduction to Engineering Management
- EMGT335 Design and Value Creation
- EMGT427 Project Management
- EMGT462 Risk Analysis and Management
- EMGT467 Economic Analysis of Engineering Projects
- EMGT472 Reliability Engineering
- EMGT524 Production/Operations Management
- EMGT527 Project Management
- MA485 Applied Linear Regression
- MA487 Design of Experiments
- ME412 Lean Manufacturing

External Examination for Six Sigma Green Belt Certification

- Take an external exam that will give students an objective credential from a recognized agency (e.g. IISE, ASQ).
- The exam is provided at no additional cost in the EMGT448 course.
- If the student intends to obtain a minor only, then they do not need to take the external exam.

Approved Six Sigma Green Belt Project for Six Sigma Green Belt Certification

- The student must submit a Six Sigma Green Belt project to be approved by the Six Sigma advisor to obtain their certification.
- If the student intends to obtain a minor only, then they do not need to submit a project to be approved by the Six Sigma advisor.

Notes and Limitations on Requirements

1. Almost all students are required to take either MA223 or MA382 as a requirement for their major; therefore, only five "extra courses" are required for most students.
2. Electives not listed above may be substituted with other courses with the approval of the minor advisor for Six Sigma.
3. All minors must be approved by the minor advisor. The department has a form for the planning and approval of a minor.
4. All certifications must be approved by the minor advisor. The department has a form for the planning and approval of a certificate.

SUSTAINABILITY MINOR

1. Curricular Requirement
    a. Core Courses (16 credits)
        i. HUM H130 Introduction to Sustainability (4 credits)
        ii. BIO107 Introduction to Environmental Science (4 credits)
        iii. ECON S151 Microeconomics (4 credits)
        iv. MDS302 Sustainability in Practice (2 credits): prerequisites: HUM H130, BIO191, ECON S151
        This is a project-based course to provide hands-on experiences for student teams working on real-world problems related to sustainability.

This could include design projects, scientific research, modeling-based

Systems Engineering is an engineering discipline whose responsibility is to create and

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