

# Rose-Hulman Institute of Technology Course Catalog

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## **MINOR IN ARTIFICIAL INTELLIGENCE**

Advisor: Michael Wollowski

Students of any major may receive the Artificial Intelligence minor.

### **Required Coursework**

Prerequisites: CSSE120, CSSE220, CSSE230

Basics: CSSE313 Artificial Intelligence.

Machine Learning: At least one of: CSSE415/MA415 Machine Learning or MA416 Deep Learning

Advanced Topics: At least 8 credits selected from CSSE453 Topics in AI, CSSE463 Image Recognition, or any upper level CSSE or MA course with a significant AI content and approved by the AI minor advisor.

Ethics: PHIL H202 Business & Engineering Ethics.

AI Project: A project with a significant AI component is required. This may be done in any discipline. Projects must be approved by the AI minor advisor. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the AI minor advisor; (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the AI minor advisor; (3) A student may complete an approved senior thesis or project involving AI and substitute a senior thesis or project course for the independent study.

Note: At most 8 credits of the AI course work (Basics, Machine Learning, and Advanced Topics) can be used to satisfy degree requirements for any major or any other minor sought by the student. The remaining credit hours can only be used to satisfy technical or free electives within the primary major.

## **MULTIDISCIPLINARY MINOR IN COGNITIVE SCIENCE**

The Multidisciplinary Minor in Cognitive Science has the following requirements:

1. Cognitive Psychology (PSYC S210)

2. Introduction to Software Development (CSSE 120)
3. Philosophy of Mind (PHIL H401) or Philosophy of Science (PHIL H402) or Human Nature (PHIL H403). The chosen course may not also satisfy requirement #4.
4. Three additional courses from the list below. At least two courses must be from the same group.
5. Substitutions may be made with the approval of the Minor Advisor.

**Courses:**

Mind and Behavior group

- ECON S356 Game Theory
- PHIL H401 Philosophy of Mind
- PHIL H403 Human Nature
- PSYC S100 Introduction to Psychology
- PSYC S110 Applied Psychology
- PSYC S310 Methods for Studying Human Behavior

Computation and Artificial Intelligence group

- CSSE 313 Artificial Intelligence
- CSSE 314 Bio-Inspired Artificial Intelligence
- CSSE 453 Topics in Artificial Intelligence
- CSSE 463 Image Recognition
- ECE 497 Evolutionary Robotics
- PSYC S410 Computational Psychology
- MA 416/CSSE 416 Deep Learning

Neuroscience group

- BE 324 Neural and Endocrine Systems Physiology with Applications
- BE 520 Introduction to Brain Machine Interfaces
- BE 543 Neuroprosthetics

**MULTIDISCIPLINARY MINOR IN DATA SCIENCE**

Any student may obtain a Multidisciplinary Minor in Data Science by taking the following courses:

Introductory Statistics Course (4 credit hours):

One of the following courses

- MA223 Engineering Statistics I
- MA382 Introduction to Statistics with Probability

Introductory Computer Science Courses (8 credit hours):

- CSSE120 Introduction to Software Development
- CSSE220 Object Oriented Software Development

Electives (16 credit hours):

Two courses from the list below:

- MA386 Statistical Programming

- MA384 Data Mining
- CSSE230 Data Structures & Algorithm Analysis

A minimum of two additional course from the list below: (See degree separation requirement below.)

- BMTH312 Bioinformatics
- CSSE313 Artificial Intelligence
- CSSE314 Bio-Inspired Artificial Intelligence
- CSSE315 Natural Language Processing
- CSSE333 Database Systems
- CSSE/MA415 Machine Learning
- CSSE/MA416 Deep Learning
- CSSE433 Advanced Database Systems
- CSSE434 Introduction to the Hadoop Ecosystem
- CSSE463 Image Recognition
- CSSE481 Web-Based Info Systems
- CSSE335/MA335 Introduction to Parallel Computing
- ECON S451 Econometrics
- MA384 Data Mining
- MA386 Statistical Programming
- MA482 Biostatistics
- MA483 Bayesian Data Analysis
- MA485 Applied Linear Regression
- PH327 Thermodynamics and Statistical Mechanics

Notes and limitations on requirements:

- Degree Separation Requirement: The Multidisciplinary Minor in Data Science must be separated from any other minor and the named required courses of any major by a minimum of 16 credit hours. Exceptions to this requirement must be approved by the minor advisor for Data Science and the heads of both the Department of Mathematics and the Department of Computer Science and Software Engineering.
- Electives not listed above may be substituted with other courses with the approval of the minor advisor for Data Science.
- The minor plan of study must be approved by the minor advisor for Data Science and the student's advisor.

## **MINOR IN ENTREPRENEURIAL STUDIES**

In a globally competitive environment, the need to rapidly transition from an innovative idea to a viable product necessitates that 21st Century engineers and scientists think and act in an entrepreneurial manner. Not everyone must be interested in starting a technology-based company, but it is important to understand the business requirements of technology commercialization. These skills help students become leaders.

To prepare students for this new workplace, the Department of Engineering Management offers a minor in Entrepreneurial Studies to complement their 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):**



Recommended electives: **CSSE/MA415 Machine Learning, ECE480/OE437, CSSE461**

Track 3: **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 4: **Creative Imaging**

Expected majors: **CS/SE, ECE, MA**

Required courses: **ARTS H244, CSSE351, ECE480**

Plus three electives from the **Imaging Electives** list below.

Recommended electives: **ARTS H142, ARTS H242, MA323**

**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)**

ARTS H142 Beginning Drawing

ARTS H242 Visual Arts in Civilization

ARTS H244 Design and Color

BE321 Biomedical Signal Processing or ECE380 Discrete-Time Signal Processing (only one can be taken as a minor elective)

BE435/OE435 Biomedical Optics

CSSE313 Artificial Intelligence

CSSE351 Computer Graphics

CSSE/MA416 Deep Learning

CSSE/MA415 Machine Learning

CSSE451 Advanced Computer Graphic

CSSE461 Computer Vision

CSSE463 Image Recognition

ECE480/OE437 Introduction to Image Processing

ECE580 Digital Signal Processing

ECE582/OE537 Advanced Image Processing

ECE584/BE541/OE584 Medical Imaging Systems

MA323 Geometric Modeling

MA371 Linear Algebra or MA373 Applied Linear Algebra

MA439 Mathematical Methods of Image Processing

NE406/NE506 Semiconductor Devices & Fabrication

OE295 Photonics Devices and Systems

OE392 Linear Optical Systems

OE480/OE580 Optical System Design

OE592 Fourier Optics and Applications



EP408 / EP508	Microsensors and Actuators	4
MDS310	Appropriate Technology for Developing Communities	4
ME430	Mechatronic Systems	4

**Software design and data analysis - include at least one course in this category**

<b>Course</b>	<b>Description</b>	<b>Hours</b>
BMTH312	Bioinformatics	4
CHE310	Numerical Methods for Chemical Engineers	4
CHE525	Process Analytics	4
CSSE386	Data Mining with Programming	4
MA335 / CSSE335	Introduction to Parallel Computing (cross-listed)	4





CHEM 582	Physical Properties of Polymeric Materials <sup>1</sup>	4	CHEM 361 or CHEM 360; Offered every 2-3 years
CHEM 270 & CHEM 470 & CHEM 570	Special Topics in Chemistry		May count more than one relevant course toward minor
ECE 416	Introduction to MEMS: Fabrication & Applications (cross-listed with CHE 405, EP 410, and ME 416)	4	Junior or Senior class standing
<b>Course</b>	<b>Description</b>	<b>Hours</b>	<b>Prerequisites</b>
ECE 419	Advanced MEMS: Modeling & Packaging (cross-listed with CHE 419 and EP 411)		

ME 517	Mechanics of Metal Forming <sup>1</sup>	4	EM 204
ME 497 & Other ME	Special Topics, requires approval of minor advisor. <sup>1</sup>		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
With permission of a minor advisor, up to four credit hours of	Physics III <sup>4</sup>	4	PH 112 and MA 112 and MA 113*
	Or		Or
PH 113	Statics & Mechanics of Materials II <sup>4</sup>		EM 121
OR			Or
EM 204	OR		BE 132
OR			
BE 222	Mechanics of Materials <sup>4</sup>		
With permission of a minor advisor, up to four credit hours of independent study and/or self-directed research		≤ 4	

<sup>1</sup> Tentative plans for electives can be found on department-specific [my.rose-hulman.edu](http://my.rose-hulman.edu) pages.

<sup>2</sup> CE majors may count CE 320 toward fulfillment of the minor even though it is in category (2)

<sup>3</sup> CHE 315 and ME 328 cannot both count toward fulfillment of the minor

<sup>4</sup> PH 113 or EM 204 or BE 222 cannot be taken as a terminal course. A materials elective that requires PH 113 or EM 204 or BE 222 as a prerequisite must also be taken in fulfillment of minor requirements.

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



- CSSE463 Image Recognition
- ECE320 Linear Control Systems<sup>3</sup>
- 8 credits of Robo Electives (see list below)

<sup>3</sup> Note, the list of additional required CPE courses appears to be 1 course longer than other tracks, but CPE students are required to take either Linear Control Systems (ECE320) or Discrete-Time Signals and Systems (ECE380) already, so the requirement to take ECE320 should not cause the CPE track to be any longer.

**(3) EE majors - Additional required courses:**

- CSSE220 Object-Oriented Software Development
- 8 credits of Robo Electives (see list below)

**(4) ME majors - Additional required courses:**

- CSSE220 Object-Oriented Software Development
- ME404 Advanced Design of Mechanisms -or- ME445 Robot Dynamics and Control
- ME406 Control Systems<sup>4</sup>
- 4 credits of Robo Electives (see list below)

<sup>4</sup> Note, the list of additional required ME courses appears to be 1 course longer than

- BE350 Biocontrol Systems
- BE520 Brain Machine Interfaces
- BE543 Neuroprosthetics
- CSSE286 Machine Learning
- CSSE313 Artificial Intelligence
- CSSE480 Cross Platform 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
- MA/CSSE415 Machine Learning
- MA/CSSE416 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 [requires approval BEFORE the course is taken]

### **MINOR IN SIX SIGMA**

Six Sigma has been incorporated by statewide and national companies involved in manufacturing, health care, and service industries. The Six Sigma process has also been used to address environmental and sustainability concerns, such as recycling and food waste/share programs. This minor is designed for students who are interested in the Six Sigma statistical methodology for process improvement and quality enhancement. Students completing the minor will develop their analytical, managerial, and statistical skills, and gain a competitive advantage in the workplace.

Minor Advisor: Dr. Diane Evans

Six Sigma Minor versus Six Sigma Certification

Any student may obtain a minor in Six Sigma by taking six or more courses (24 credit hours) from the lists below. To additionally obtain a Green Belt Certification, the student must pass an external Six Sigma exam and submit a Six Sigma Green Belt project that must be approved by the Six Sigma minor advisor.

Introductory Statistics Course (4 credit hours):

One of the following courses:

- MA223 Engineering Statistics I
- MA382 Introduction to Statistics with Probability

Note: If MA 381 is taken before MA223/MA382, it is strongly recommended the student take MA382 instead of MA223.

Quality and Six Sigma Courses (12 credit hours):

- EMGT445 Quality Methods
- EMGT446 Statistical Methods in Six Sigma
- 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
- EMGT E524 Production/Operations Management
- EMGT E527 Project Management
- EMGT 548 Six Sigma BoK
- 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 (IISE).
- Students who pass the EMGT548 IISE SSGB exam will be reimbursed for the exam (while funding is available)
- 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. Core Courses (12 credits)
  - a. HUM H130 Introduction to Sustainability (4 credits)
  - b. BIO 107 Introduction to Environmental Science (4 credits)
  - c. ECON S151 Introduction to Microeconomics (4 credits) or ECON S152 Introduction to Macroeconomics (4 credits)
2. Three electives (4 credits each = 12 credits) Students must take a total of at least four credits from a list of Cultural and Social courses and at least four credits from a list of Technical and Scientific courses, with the remaining four credits covered in either category. Alternatively, students can design their own plan of study for elective courses that suit their interests and field of study with approval of the Sustainability Minor Advisor.
  - a. Cultural and Social (HSSA requirement)
    - ANTH S101 Introduction to Anthropology
    - ECON S351 Environmental Economics
    - ENGL H349 Nature and Literature
    - HIST H322 Disasters and Modern Society
    - HIST H425 Cities and Technology in the Industrial Age
    - PHIL H201 Bioethics
    - PHIL H202 Business and Engineering Ethics
    - RELG H201 Nature and Religion
  - b. Technical and Scientific (Discipline Specific Tech Elective)
    - BIO220 Microbiology (prerequisite: BIO110)
    - BIO320 Ecology (prerequisite: BIO130)
    - CE250 Sustainable Civil Engineering Design (2 credits)
    - CE460 Introduction to Environmental Engineering
    - CE471 Water Resources Engineering
    - CHE465 Energy and the Environment
    - CHEM535 Toxicology for Chemists
    - CHEM556 Green Chemistry
    - CSSE241 Computing in a Global Society
    - ECE371 Sustainable Energy Systems (prerequisite: ECE204)
    - EMGT587 Systems Engineering
    - ME408 Renewable Energy (prerequisite: ES212)
    - MDS201 Global Engineering and the Social Context I

### **MULTIDISCIPLINARY MINOR IN SYSTEMS ENGINEERING**

Systems Engineering is an engineering discipline whose responsibility is to create and execute an interdisciplinary process to ensure that all system stakeholders' needs are satisfied in a high-quality, trustworthy, cost-efficient, and schedule compliant manner

throughout a system's entire life cycle. The field of systems engineering provides a broad spectrum of tools that can be used to help engineers manage complexity, predict and address risk, ensure safety, gather and manage information, and provide solutions with greater value to the intended stakeholders. The Minor in Systems Engineering aims to provide students with a broad exposure to systems engineering concepts and tools. Hence, they are better prepared to integrate knowledge and collaborate effectively across different disciplinary domains to create value for their systems and ensure long-term system success.

Minor Advisor: Dr. Eva Andrijcic

Students are required to take the following courses:

- EMGT E564 – Systems Architecture
- EMGT 583 – Management Information Systems
- EMGT 584 – Systems Thinking and Evaluation

Additionally, students are required to attend three hours of systems-related seminars offered at Rose-Hulman or by an external organization. Examples of appropriate seminars would include INCOSE Great Lakes systems seminars, which are offered virtually every month and are open to students, seminars or presentations offered at Rose-Hulman, which address some aspect of the systems engineering process. Finally, students are required to document their attendance by writing a brief reflection about what they have learned. All three reflections must be reviewed and approved by the minor advisor prior to minor completion.

Students must take additional three courses from the following list of electives:

- EMGT 472 – Reliability Engineering
- EMGT E572 – Reliability Engineering
- EMGT 427 – Project Management
- EMGT E527 – Project Management
- EMGT 497 – Special Topics in Systems Engineering
- EMGT E561 – Failures of Engineered Systems
- EMGT 467/567 – Economic Analysis of Engineering Projects
- EMGT 462/562 – Risk Analysis and Management
- EMGT E589 – Manufacturing Systems
- MA 444 – Deterministic Models in Operations Research
- MA 445 – Stochastic Models in Operations Research
- ECE 370 – Energy Systems
- ME 430 – Mechatronic Systems

Other Engineering Management courses can be considered in completing the minor. Additionally, Special Topics Courses must be approved as SE Minor Electives by SE Minor Advisor and Department Head of Engineering Management.

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