PHYSICS

Overview and Contact Information
Consulting with a departmental advisor, the student may design their major curriculum for various purposes. They may take the courses necessary to prepare for graduate study in physics or closely related fields (including engineering), or they may plan a program that, together with courses from other disciplines, prepares them for advanced work in medicine, environmental engineering, or other physical sciences or branches of engineering, as well as for secondary school teaching, technical writing, or technical positions in industry. Students interested in geophysics, astrophysics, materials science, biophysics, physical chemistry, and other similar programs can work out special majors in consultation with faculty in the appropriate departments.

See Also
- Engineering (http://catalog.mtholyoke.edu/areas-study/ engineering/)
- Dual-Degree in Engineering (http://catalog.mtholyoke.edu/ other-programs/other-degree-certificate-programs/)

Contact Information
Alexi Arango, Chair
Nicole Amrani, Academic Department Coordinator
206 Kendade Hall
413-538-2238
https://www.mtholyoke.edu/acad/physics (https://www.mtholyoke.edu/acad/physics/)

Learning Goals
Graduating physics majors will be prepared for graduate work in the sciences and engineering, or a wide variety of careers in teaching, industry, or public service. Students will be prepared to:

• Apply their physical reasoning and analytic skills to tackle complex problems in a variety of academic, research, and innovative work environments; and alternative careers.
• Synthesize and apply sophisticated mathematical and physical models to complex, real-world problems.
• Apply knowledge and skills gained in the physics major toward broader goals, including social issues, environmental concerns, and daily problems.
• Engage in self-directed learning by consulting the necessary resources and building knowledge of their own strengths and weaknesses.
• Know when and how to quickly address challenging questions.
• Be a strong, confident physics major who embarks in the world and can apply their analytical skills to quickly address questions when appropriate and think deeply and at length when needed.

Physics majors will develop strong problem solving skills. Students will:

• Be able to plan an effective approach to challenging problems.
• Use proportional, conceptual, analytical, numerical, computational, and qualitative reasoning, distinguishing when each is appropriate.
• Learn to critically evaluate their assumptions, methodology and results, and to revise their approach as needed.
• Develop cooperative group problem solving skills, engaging in effective communication, planning and evaluation.
• Develop confidence and skills to independently solve complex problems.
• Develop the metacognitive skills required to engage in self-assessment of their own strategies and approaches.

Physics majors will develop strong technical skills. Students will:

• Develop strong mathematical skills required to address technical scientific problems.
• Gain hands-on experimental skills, including common methodology, experimental design, troubleshooting, analysis, and interpretation.
• Acquire computational skills, including numerical methods, implementation of models, visualization of results, and analysis of data sets.
• Understand how to read, interpret, and evaluate technical articles, and how to perform literature searches.

Physics majors will develop strong communication skills. Students will:

• Clearly articulate complex technical ideas in speech in preparation for both formal and informal scientific settings.
• Clearly articulate complex technical ideas in writing in preparation for both formal and informal scientific settings.
• Be able to explain complex science to the general public.
• Communicate effectively in collaborative group settings.
• Effectively ask and respond to questions with confidence.

Physics majors will develop an appreciation for how physics and science enriches their experience of the world. Students will:

• Understand the technical role of science in the modern world; for example, applications of scientific reasoning to policy decisions, technological innovations, etc.
• Consider the complex intersection of science and culture, including public opinion, power structures, and changing norms.
• Appreciate how science progresses as an evolving, self-correcting process.
• Specifically, appreciate the historical and philosophical developments in physics.
• Develop an appreciation of physics as a discipline that develops quantitative models, based on foundational principles, resulting in specific predictions to be tested by experiment, to describe the world.
• Appreciate the relationship of physics to the other sciences, and the interdisciplinary nature of modern challenges.

Faculty
This area of study is administered by the Department of Physics:
Katherine Aidala, Kennedy-Schelkunoff Professor of Physics; Director of the Fimbel Maker Innovation Lab
Alexi Arango, Associate Professor of Physics
Kerstin Nordstrom, Associate Professor of Physics, On Leave 2021-2022
Spencer Smith, Assistant Professor of Physics
Desalegn Debu, Visiting Lecturer in Physics
Rachel Koh, Visiting Lecturer in Physics
Requirements for the Major

A minimum of 37 credits:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>As a prerequisite for PHYS-110:</td>
<td></td>
<td></td>
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<tr>
<td>MATH-101</td>
<td>Calculus I</td>
<td></td>
</tr>
<tr>
<td>PHYS-110</td>
<td>Force, Motion, and Energy 1</td>
<td>4</td>
</tr>
<tr>
<td>As a prerequisite for PHYS-201:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH-102</td>
<td>Calculus II</td>
<td></td>
</tr>
<tr>
<td>PHYS-201</td>
<td>Electromagnetism 1</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-205</td>
<td>Introduction to Mathematical Methods for Scientists</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-210</td>
<td>Waves and Optics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-250</td>
<td>Quantum Mechanical Phenomena</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-231</td>
<td>Techniques of Experimental Physics 2</td>
<td>1</td>
</tr>
<tr>
<td>Students must also take two of:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS-315</td>
<td>Analytical Mechanics</td>
<td>8</td>
</tr>
<tr>
<td>PHYS-325</td>
<td>Electromagnetic Theory</td>
<td></td>
</tr>
<tr>
<td>PHYS-326</td>
<td>Statistical Mechanics and Thermodynamics</td>
<td></td>
</tr>
</tbody>
</table>

Laboratory Work:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-220</td>
<td>Intermediate Lab in Physics or PHYS-308 Electronics</td>
<td>4</td>
</tr>
</tbody>
</table>

And 4 additional credits of laboratory work from:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-295</td>
<td>Independent Study</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-295P</td>
<td>Independent Study with Practicum</td>
<td></td>
</tr>
<tr>
<td>PHYS-395</td>
<td>Independent Study</td>
<td></td>
</tr>
<tr>
<td>PHYS-395P</td>
<td>Independent Study with Practicum</td>
<td></td>
</tr>
<tr>
<td>PHYS-220 or PHYS-308, if you didn't count it already above or laboratory courses offered at other institutions, as arranged on a case-by-case basis.</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Total Credits 37

1 Students who can demonstrate proficiency in one or both introductory courses by taking placement exams administered by the department may begin their physics study at the appropriate level but must still complete 37 credits of college-level physics courses for the major.

2 PHYS-231 should be taken during the junior or senior year as arranged on a case-by-case basis.

3 PHYS-336 (offered in alternate years) is recommended, as is PHYS-326 or laboratory courses offered at other institutions, as arranged on a case-by-case basis.

Additional Specifications

- Physics majors are also encouraged to take CHEM-150.
- MATH-203 (Calculus III – multivariate calculus) and MATH-211 (linear algebra), while not required, are recommended for those students planning to take advanced physics courses or to pursue graduate study. MATH-302 (complex analysis) and MATH-333 (differential equations) are also recommended for students planning to pursue graduate study in physics or engineering.
- Students planning to pursue graduate study in physics are encouraged to take at least one graduate-level course in physics at UMass.
- For advising purposes, several Plans of Study (http://catalog.mtholyoke.edu/areas-study/chemistry/#planofstudytext), showing recommended sequences of course-taking to complete the major are available.

Sample Plans of Study for the Physics Major

Courses with a footnote are required for the major.

The recommended programs are based on the assumption that the student will undertake an independent project leading to honors in the fourth year. It is important for students to take mathematics courses which teach the specific skills needed for physics. Both integral and differential calculus are necessary for mathematical manipulation of formulas in the introductory physics courses.

Elective courses include:

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>PHYS-220</td>
<td>Intermediate Lab in Physics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-295</td>
<td>Independent Study</td>
<td>1-4</td>
</tr>
<tr>
<td>PHYS-308</td>
<td>Electronics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-336</td>
<td>Quantum Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-395</td>
<td>Independent Study</td>
<td>1-8</td>
</tr>
</tbody>
</table>

Or a wide range of Five College options

For students beginning physics in the first semester of the first year:

First Year

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-110</td>
<td>Force, Motion, and Energy 1</td>
<td>4</td>
</tr>
<tr>
<td>MATH-102</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-201</td>
<td>Electromagnetism 1</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-205</td>
<td>Introduction to Mathematical Methods for Scientists</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-210</td>
<td>Waves and Optics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-250</td>
<td>Quantum Mechanical Phenomena</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-231</td>
<td>Techniques of Experimental Physics 2</td>
<td>1</td>
</tr>
</tbody>
</table>

Sophomore

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-205</td>
<td>Electromagnetism 1</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-210</td>
<td>Introduction to Mathematical Methods for Scientists</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-308</td>
<td>Quantum Mechanical Phenomena</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-336</td>
<td>Techniques of Experimental Physics 2</td>
<td>1</td>
</tr>
<tr>
<td>PHYS-395</td>
<td>Independent Study</td>
<td>8</td>
</tr>
</tbody>
</table>

Junior

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-308 (or elective)</td>
<td>Electrons</td>
<td>4</td>
</tr>
<tr>
<td>PHYS-326</td>
<td>Quantum Mechanical Phenomena</td>
<td>4</td>
</tr>
</tbody>
</table>

Senior

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-325</td>
<td>Electrons</td>
<td>4</td>
</tr>
</tbody>
</table>
For students beginning physics in the second semester of the first year:

First Year
Fall Credits Spring Credits
MATH-102 4 MATH-102 4
PHYS-110 4
Total Credits 8

Sophomore
Fall Credits Spring Credits
PHYS-201 4 PHYS-220 (or elective) 4
PHYS-205 4 PHYS-315 4
Total Credits 8

Junior
Fall Credits Spring Credits
PHYS-210 4 PHYS-250 4
PHYS-395 or 308 1-8 Physics elective
Total Credits 1-8

Senior
Fall Credits Spring Credits
PHYS-325 4 PHYS-395 1-8
PHYS-326 4 Physics elective
Total Credits 1-8

Total Credits 4-60

Requirements for the Minor
A minimum of 16 credits:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS-201</td>
<td>Electromagnetism</td>
<td>4</td>
</tr>
<tr>
<td>Any three of:</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>PHYS-205</td>
<td>Introduction to Mathematical Methods for Scientists</td>
<td></td>
</tr>
<tr>
<td>PHYS-210</td>
<td>Waves and Optics</td>
<td></td>
</tr>
<tr>
<td>PHYS-250</td>
<td>Quantum Mechanical Phenomena</td>
<td></td>
</tr>
<tr>
<td>PHYS-308</td>
<td>Electronics</td>
<td></td>
</tr>
</tbody>
</table>

Total Credits 16

For students beginning physics in the first sophomore semester:

First Year
Fall Credits Spring Credits
MATH-101 4 MATH-102 4

Sophomore
Fall Credits Spring Credits
PHYS-110 4 PHYS-201 4

Junior
Fall Credits Spring Credits
PHYS-205 4 PHYS-220 (or elective) 4
PHYS-210 4 PHYS-250 4
Total Credits 8

Senior
Fall Credits Spring Credits
PHYS-325 4 PHYS-395 1-8
PHYS-326 4 Physics elective

Total Credits 4-60

Teacher Licensure
Students interested in pursuing licensure in the field of physics can combine their course work in physics with a minor in education. In some instances, course work in the major coincides with course work required for licensure; in other cases, it does not. For specific course requirements for licensure within the major of physics, please consult your advisor or the chair of the physics department. Further information about the minor in education (http://catalog.mtholyoke.edu/areas-study/psychology-education/#minorertext) and the Teacher Licensure program (http://catalog.mtholyoke.edu/areas-study/psychology-education/#teacherlicensuretext) is available in other sections of the catalog, and consult Professor Lawrence in the psychology and education department.

Licensure also requires a formal application, as well as passing scores on the Massachusetts Test of Educator Licensure (MTEL) in both the literacy component and the subject matter component. Copies of the test objectives for the MTEL are available in other sections of the catalog, and in the Department of Psychology and Education.

Additional information about the Licensure Program, including application materials, can be found on the Teacher Licensure Program website (https://www.mtholyoke.edu/acad/teacherlicensure/).

Course Advice
Getting Started in Physics
Entering students considering a major in physics are strongly urged to take PHYS-110 in the first year. While it is possible to complete the major by taking PHYS-110 and PHYS-201 as late as the second year, such a
program is not recommended because this delay limits the student’s opportunities for advanced electives or honors work.

**Introductory Courses and Distribution Requirements**

PHYS-100–PHYS-150 is a non-calculus introductory course sequence in physics, appropriate for students in the life sciences and for students with a general, nonprofessional interest in physics. This sequence satisfies the physics requirements of medical school.

PHYS-110–PHYS-201 is a calculus-based introductory course sequence in physics, appropriate for students intending to major in a physical science. To major in physics, a student must complete PHYS-201 by the end of the sophomore year. A student with excellent preparation in physics may take a departmental placement exam to place out of one or both of these introductory courses. Any 200 or 300-level 4-credit physics course will then count for distribution in physics. PHYS-110 and PHYS-201 do not cover the full range of topics on the MCAT syllabus; the PHYS-100 and PHYS-150 sequence has a better coverage of these topics.

**Course Offerings**

**PHYS-100 Foundations of Physics**

_Fall. Credits: 4_  
This course studies a variety of topics in physics unified by the physical notions of force, energy, and equilibrium. Mathematics is used at the level of geometry, proportion, and dimensional analysis. Topics, drawn from the MCAT syllabus, include geometrical optics, time, oscillation, statics, elasticity, conservation of energy, and fluids.  
**Applies to requirement(s):** Math Sciences 
**The department**  
**Coreq:** PHYS-100L  
**PHYS-104 Renewable Energy**

_Spring. Credits: 4_  
We will examine the feasibility of converting the entire energy infrastructure of the US from one that is dependent on fossil fuels to one that utilizes mostly renewable sources of energy. We will examine the potential scale of energy production and the associated costs, natural resource requirements and land usage needs for both renewables, such as solar, wind and biofuel, and non-renewables, such as coal, natural gas, petroleum and nuclear. By applying extensive use of basic algebra and an elementary understanding of the physical processes underpinning each energy technology, we will arrive at a number of urgent conclusions about the challenges facing our energy infrastructure.  
_Crosslisted as: ENVST104_  
**Applies to requirement(s):** Math Sciences  
A. Arango  
**PHYS-110 Force, Motion, and Energy**

_Fall and Spring. Credits: 4_  
Studies the mechanics of material objects. Topics include Newton’s laws, projectile motion, circular motion, momentum, kinetic and potential energy, angular momentum, gravitation, and oscillations. This course is appropriate for students intending to major in a physical science.  
**Applies to requirement(s):** Math Sciences  
J. Young  
**Prereq:** MATH-101 or equivalent. **Coreq:** PHYS-110L.  
**Advisory:** Knowledge of calculus as demonstrated by MATH-101 or equivalent.
PHYS-220 Intermediate Lab in Physics
Spring. Credits: 4
This lab-based course is an introduction to modern, investigative, experimental physics. The course is intended as a bridge between the structured introductory lab experience and independent research. In addition to exploring key physical phenomena crucial to modern understandings and gaining familiarity with modern experimental apparatus and techniques, students complete exploratory projects of various sorts and then extended, multi-week experimental projects, participating in experimental design, construction, debugging and implementation. Students will present and interpret their experimental results and develop follow-up questions which they will answer experimentally. This course will introduce students to scientific communications skills and is speaking- and writing-intensive.
Applies to requirement(s): Meets No Distribution Requirement
Other Attribute(s): Speaking-Intensive, Writing-Intensive
N. Abraham
Prereq: PHYS-201.

PHYS-231 Techniques of Experimental Physics
Fall and Spring. Credits: 1
Provides training in the techniques employed in the construction of scientific equipment.
Applies to requirement(s): Meets No Distribution Requirement
C. Trimble
Restrictions: This course is limited to Physics majors.; This course is open to juniors and seniors
Notes: 1 meeting (2 hours) for 3 weeks. Credit/no credit grading.

PHYS-250 Quantum Mechanical Phenomena
Spring. Credits: 4
This course provides an introduction to quantum mechanics. The Uncertainty Principle, Schroedinger’s Equation, and the hydrogen atom are studied in depth, with emphasis on angular momentum, electron spin, and the Pauli Exclusion Principle.
Applies to requirement(s): Math Sciences
N. Abraham

PHYS-290 Advanced Laboratory Practicum
Spring. Credits: 1 - 8
This course is a hands-on practicum, intended to introduce students to the practice of modern physics research. Depending on student interest, topics include external research seminars by practitioners in the field, training in oral and written scientific communication, presentation and interpretation of research results, scientific modeling, and hands-on experimental skills. Research projects are an integral part of this course; credit will be apportioned in relation to the intensity of the project.
Applies to requirement(s): Meets No Distribution Requirement
Other Attribute(s): Speaking-Intensive, Writing-Intensive
K. Aidala
Instructor permission required.
Notes: Repeatable for credit.

PHYS-295 Independent Study
Fall and Spring. Credits: 1 - 4
The department
Instructor permission required.

PHYS-295P Independent Study with Practicum
Fall and Spring. Credits: 1 - 4
The department
Instructor permission required.

PHYS-308 Electronics
Fall. Credits: 4
This course is a study of electrical circuits and components with emphasis on the underlying physical principles; solid-state active devices with applications to simple systems such as linear amplifiers; feedback-controlled instrumentation; and analog and digital computing devices.
Applies to requirement(s): Math Sciences
K. Aidala
Prereq: PHYS-150 or PHYS-201.
Notes: Meetings combine lecture and hands-on lab

PHYS-311 Computational Physics Laboratory
Not Scheduled for This Year. Credits: 4
Computers bring a new dimension to the mathematical theories of physics, including new methods of visualization and new ways to explore theory through computer experiments. This laboratory course will combine mathematics, physics, and computation in projects that make essential use of all three together. Topics from various subfields of physics will be packaged into self-contained modules for exploration through the use of high-level computational tools.
Applies to requirement(s): Math Sciences
The department
Prereq: PHYS-205.

PHYS-315 Analytical Mechanics
Spring. Credits: 4
Newton’s great innovation was the description of the world by differential equations, the beginning of physics as we know it. This course studies Newtonian mechanics for a point particle in 1, 2, and 3 dimensions, systems of particles, rigid bodies, and the Lagrangian and Hamiltonian formulations.
Applies to requirement(s): Math Sciences
S. Smith
Prereq: PHYS-205.

PHYS-325 Electromagnetic Theory
Spring. Credits: 4
This course presents the development of mathematical descriptions of electric and magnetic fields; study of interactions of fields with matter in static and dynamic situations; mathematical description of waves; and development of Maxwell’s equations with a few applications to the reflection and refraction of light and microwave cavities.
Applies to requirement(s): Math Sciences
The department

PHYS-326 Statistical Mechanics and Thermodynamics
Fall. Credits: 4
This course presents thermodynamic and statistical descriptions of many-particle systems. Topics include classical and quantum ideal gases with applications to paramagnetism; black-body radiation; Bose-Einstein condensation; and the Einstein and Debye solid; the specific heat of solids.
Applies to requirement(s): Math Sciences
K. Nordstrom
Prereq: Quantum Mechanical Phenomena (PHYS-250) and Intro to Math Methods (PHYS-205) or permission from department.
PHYS-336 Quantum Mechanics
Not Scheduled for This Year. Credits: 4
This course is an introduction to formal quantum theory: the wave function and its interpretation, observables and linear operators, matrix mechanics and the uncertainty principle; solutions of one-dimensional problems; solutions of three-dimensional problems and angular momentum; and perturbative methods.
Applies to requirement(s): Math Sciences
The department
Prereq: PHYS-250.

PHYS-390 Advanced Laboratory Practicum
Spring. Credits: 1 - 8
This course is a hands-on practicum, intended to introduce students to the practice of modern physics research. Depending on student interest, topics include external research seminars by practitioners in the field, training in oral and written scientific communication, presentation and interpretation of research results, scientific modeling, and hands-on experimental skills. Research projects are an integral part of this course; credit will be apportioned in relation to the intensity of the project.
Applies to requirement(s): Meets No Distribution Requirement
Other Attribute(s): Speaking-Intensive, Writing-Intensive
K. Aidala
Instructor permission required.
Prereq: 16 credits in Physics.
Notes: Repeatable for credit.

PHYS-395 Independent Study
Fall and Spring. Credits: 1 - 8
The department
Instructor permission required.

PHYS-395P Independent Study with Practicum
Fall and Spring. Credits: 1 - 8
The department
Instructor permission required.