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:

- Communicate effectively in collaborative group settings.
- Effectively ask and respond to questions with confidence.
- 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, Professor of Physics
Mark Peterson, Professor of Physics and Mathematics on the Alumnae Foundation
Alexi Arango, Associate Professor of Physics
Kerstin Nordstrom, Associate Professor of Physics
Spencer Smith, Assistant Professor of Physics, On Leave 2020-2021
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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<tbody>
<tr>
<td>PHYS-110</td>
<td>Force, Motion, and Energy 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>

Students must also take two of:

- PHYS-315 Analytical Mechanics
- PHYS-325 Electromagnetic Theory
- PHYS-326 Statistical Mechanics and Thermodynamics

Laboratory Work:

- PHYS-220 Intermediate Lab in Physics or PHYS-308 Electronics 4
- And 4 additional credits of laboratory work from:
  - PHYS-295 Independent Study
  - PHYS-295P Independent Study with Practicum
  - PHYS-395 Independent Study
  - PHYS-395P Independent Study with Practicum
  - 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. 3

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

3 As arranged on a case-by-case basis

4 PHYS-336 (offered in alternate years) is recommended, as is MATH-211.

Additional Specifications

- Course substitutions for the above requirements will be allowed on a case-by-case basis where it makes sense for a student’s academic goals; for example, a student interested in materials science might reasonably replace PHYS-315 with CHEM-208.
- Up to 4 credits of PHYS-295P or PHYS-395P may be earned through summer research, following college guidelines for awarding PHYS-295P/PHYS-395P credit. Note that PHYS-295P and PHYS-395P credit must be arranged with the department before the summer research experience begins; typically, a single eight to ten-week summer research program will account for no more than 2 credits of PHYS-295P or PHYS-395P.
- Normally, no more than 12 credits of PHYS-295, PHYS-295P, PHYS-395, or PHYS-395P will count towards the major.
- 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>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<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>
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</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>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHYS-110 1</td>
<td>4</td>
<td>PHYS-201 1</td>
<td>4</td>
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<tr>
<td>MATH-102</td>
<td>4</td>
<td>MATH-203</td>
<td>4</td>
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Sophomore

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<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS-205 1</td>
<td>4</td>
<td>PHYS-250 1</td>
<td>4</td>
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<tr>
<td>PHYS-210 1</td>
<td>4</td>
<td>PHYS-315</td>
<td>4</td>
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Junior

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS-308 (or elective)</td>
<td>4</td>
<td>PHYS-220 (or elective)</td>
<td>4</td>
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<tr>
<td>PHYS-326</td>
<td>4</td>
<td>PHYS-336</td>
<td>4</td>
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Senior

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<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-325</td>
<td>4</td>
<td>PHYS-395</td>
<td>1-8</td>
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</table>
### 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>
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</tbody>
</table>

Total Credits 16

1 Other combinations of courses are also possible with permission of the department chair. Courses must be at or above the 200 level in Physics.

### 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/#minortext) 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/teach/).

### 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*

*K. Nordstrom*

*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: ENVST 104*

*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*

*K. Aidala*

*Prereq: MATH-101 or equivalent. Coreq: PHYS-110L. Advisory: Knowledge of calculus as demonstrated by MATH-101 or equivalent.*

**PHYS-112 Electricity and Magnetism**

*Fall and Spring. Credits: 4*

Studies the concepts of electricity and magnetism. Topics include electric and magnetic fields, the Lorentz force, conductors, magnetic forces, and magnetic fields. This course is appropriate for students intending to major in a physical science.

*Applies to requirement(s): Math Sciences*

*K. Aidala*

*Prereq: MATH-101 or equivalent. Coreq: PHYS-110L. Advisory: Knowledge of calculus as demonstrated by MATH-101 or equivalent.*

**PHYS-132 Engineering for Everyone**

*Not Scheduled for This Year. Credits: 4*

Engineers change the world we live in every day by developing and improving nearly every aspect of our lives. In this course, we will study the interaction of technology and society and how the engineering design process helps shape the world we live in. Engineering comprises many disciplines, but one common theme is the engineering design process: research, problem definition, feasibility, conceptualization, prototyping, and testing. In this class, students will learn the engineering design process through application to contemporary technological and societal issues put into practice with pitch presentations, design reviews, prototypes, and written reports.

*Applies to requirement(s): Math Sciences*

*K. McTiernen*

*Advisory: This course has no prerequisites and is recommended for all students interested in engineering and technology.*

*Notes: Students interested in continuing with the Engineering Nexus are strongly recommended to take the course.*

**PHYS-141 Interweaving Themes in Physics and Art**

*Not Scheduled for This Year. Credits: 4*

Physics and Art represent the world in seemingly different ways, however they share many common themes: the guiding role of symmetry, the tension between order and disorder, and the emergence of structure from many simple constituents. We will explore some of the big ideas in physics, including quantum mechanics, relativity, entropy, and chaos theory, by looking at how these underlying themes are represented in the visual arts. Islamic tessellations, Japanese Suminagashi paper marbling, as well works by contemporary artists such as Tara Donovan will guide us toward an intuitive understanding of some of the most exciting ideas in physics without the need for any prior physics background.

*Applies to requirement(s): Math Sciences*

*S. Smith*

**PHYS-150 Phenomena of Physics**

*Spring. Credits: 4*

This course studies a variety of topics in physics, drawn from the MCAT syllabus, including thermodynamics, acoustics, wave optics, electricity, magnetism, and nuclear phenomena. As in Physics 100, the applicable mathematics is geometry, proportion, and dimensional analysis.

*Applies to requirement(s): Math Sciences*

*The department*

*Prereq: PHYS-100 or PHYS-110. Coreq: PHYS-150L.*

**PHYS-201 Electromagnetism**

*Fall and Spring. Credits: 4*

Topics include: electromagnetism, emphasizing fields and energy, electrostatics; electric circuits; magnetism; induction; and electromagnetic radiation. Additional topics chosen according to the interests of the class and instructor.

*Applies to requirement(s): Math Sciences*

*A. Arango*

*Prereq: PHYS-110 and MATH-102. Coreq: PHYS-201L.*
PHYS-205 Introduction to Mathematical Methods for Scientists
Fall. Credits: 4
Topics include Taylor series, complex numbers, partial differentiation, multiple integration, selected topics in linear algebra and vector calculus, ordinary differential equations, and Fourier series. The course includes a weekly computational lab using Python, in addition to a traditional emphasis on analytic solutions.
Applies to requirement(s): Math Sciences
A. Arango
Prereq: PHYS-201 (or concurrent enrollment with permission). Coreq: PHYS-205L.

PHYS-210 Waves and Optics
Spring. Credits: 4
A comprehensive treatment of wave phenomena, particularly light, leading to an introductory study of quantum mechanics. Topics include wave propagation, polarization, interference and interferometry, diffraction, and special relativity.
Applies to requirement(s): Math Sciences
A. Arango
Prereq: Electromagnetism (PHYS-201) and Intro to Math Methods (PHYS-205) or concurrent enrollment in PHYS-205 with permission.

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
Not Scheduled for This Year. 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
The department
Prereq: PHYS-150 or PHYS-201.
Notes: Meetings combine lecture and hands-on lab

PHYS-311 Computational Physics Laboratory
Fall. 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
M. Peterson
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
The department
Prereq: PHYS-205.
**PHYS-325 Electromagnetic Theory**  
*Not Scheduled for This Year. 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*  
*M. Peterson*  
*Prereq: PHYS-205 and PHYS-210.*

**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-328 From Lilliput to Brobdingnag: Bridging the Scales Between Science and Engineering**  
*Not Scheduled for This Year. Credits: 4*

The performance of many engineered devices is dependent on macroscopic factors (pressure, temperature, flow, conductivity). As a result, engineers often model devices macroscopically considering atomistic level details only through fixed parameters. These parameters do not always capture the full atomistic level picture. More accurate multi-scale approaches for modeling macroscopic properties use basic atomistic level chemistry at key points in larger scale simulations. This course is an introduction to such approaches focusing on fuel cells as a concrete example. Basic scientific principles will be developed alongside basic engineering principles through project/case studies.

*Croslisted as: CHEM-328*

*Applies to requirement(s): Meets No Distribution Requirement*  
*Other Attribute(s): Writing-Intensive*  
*M. Gomez*  
*Prereq: MATH-102 and any chemistry or physics course with grade of C or better.*

**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*  
*M. Peterson*  
*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.*

**PHYS-395 Independent Study**  
*Fall and Spring. Credits: 1 - 8*

The department  
*Instructor permission required.*