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
Katherine Aidala, Chair
Nicole Amrani, Academic Department Coordinator
206 Kendade Hall
413-538-2238
https://www.mtholyoke.edu/acad/physics

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, Clare Boothe Luce Assistant Professor of Physics
Spencer Smith, Assistant Professor of Physics

Requirements for the Major
A minimum of 37 credits:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>As a prerequisite for PHYS-110:</td>
<td></td>
</tr>
<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>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>

Students must also take two of:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-315</td>
<td>Analytical Mechanics</td>
<td></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</td>
<td>4</td>
</tr>
<tr>
<td>or PHYS-308</td>
<td>Electronics</td>
<td></td>
</tr>
<tr>
<td>And 4 additional credits of laboratory work from:</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>PHYS-295</td>
<td>Independent Study</td>
<td></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</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>or laboratory courses offered at other institutions, as arranged on a case-by-case basis. ³</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Credits


1 Students who can demonstrate proficiency in one or both introductory courses by taking placement exams administered by the department may begin their physics studies 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-101 and/or CHEM-201 (General Chemistry I and II).
- 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/#planofstudystext), 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>
</tr>
</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>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-110</td>
<td>4 PHYS-201</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>MATH-102</td>
<td>4 MATH-203</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Sophomore**

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

**Junior**

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

**Senior**

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

Total Credits 54-68

1 Required for the major

For students beginning physics in the first sophomore semester:

**First Year**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH-101</td>
<td>4 MATH-102</td>
<td>4</td>
<td></td>
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</table>

**Sophomore**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-110</td>
<td>4 PHYS-201</td>
<td>4</td>
<td></td>
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</tbody>
</table>

**Junior**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-205</td>
<td>4 PHYS-220 (or elective)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>PHYS-210</td>
<td>4 PHYS-250</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Senior**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-325</td>
<td>4 PHYS-395</td>
<td>1-8</td>
<td></td>
</tr>
<tr>
<td>PHYS-326</td>
<td>4 Physics elective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS-395 or 308</td>
<td>1-8</td>
<td></td>
<td></td>
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</tbody>
</table>

Total Credits 42-56

1 Required for the major

• PHYS-231 should be taken during the junior or senior year
• PHYS-336, offered in alternate years, is recommended, as is MATH-211.

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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<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>
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</tbody>
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### Introductory Courses and Distribution Requirements

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS-100</td>
<td>Foundations of Physics</td>
</tr>
<tr>
<td>PHYS-100L</td>
<td>Foundations of Physics Lab</td>
</tr>
<tr>
<td>PHYS-104</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>PHYS-110</td>
<td>Force, Motion, and Energy</td>
</tr>
<tr>
<td>PHYS-110L</td>
<td>Force, Motion, and Energy Lab</td>
</tr>
<tr>
<td>PHYS-115</td>
<td>Mechanics of Material Objects</td>
</tr>
<tr>
<td>PHYS-115L</td>
<td>Mechanics of Material Objects Lab</td>
</tr>
<tr>
<td>PHYS-150</td>
<td>Quantum Mechanical Phenomena</td>
</tr>
<tr>
<td>PHYS-150L</td>
<td>Quantum Mechanical Phenomena Lab</td>
</tr>
<tr>
<td>PHYS-201</td>
<td>Electronics</td>
</tr>
<tr>
<td>PHYS-201L</td>
<td>Electronics Lab</td>
</tr>
</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.

### 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*

S. Smith

*Prereq: MATH-101 or equivalent. Coreq: PHYS-110L.*

*Advisory: Knowledge of calculus as demonstrated by MATH-101 or equivalent.*

**PHYS-115 Mechanics of Material Objects**

*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*

S. Smith

**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*  
*K. Nordstrom*  
*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 infinite series, complex numbers, partial differentiation, multiple integration, selected topics in linear algebra and vector analysis, ordinary differential equations, and Fourier series. The course includes a brief introduction to Mathematica and Matlab, in addition to a traditional emphasis on analytic solutions.  
*Applies to requirement(s): Math Sciences*  
*S. Smith*  
*Prereq: PHYS-201 (or concurrent enrollment with permission). Coreq: PHYS-205L.*  

PHYS-210 Waves and Optics  
*Fall.* 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. Students will engage in a semester-long experimental project, participating in experimental design, construction, debugging and implementation. Students will practice presenting and interpreting experimental results and will be encouraged to develop follow-up experimental questions of their own. This course will also introduce students to scientific communication 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*  
*Prereq: PHYS-205 and PHYS-210.*  

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*  
*The department*  
*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-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."

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PHYS-325 Electromagnetic Theory  
*Fall. 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): Intro to Math Methods (PHYS-205).*

M. Peterson  
*Prereq: Intro to Math Methods (PHYS-205)."

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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): Intro to Math Methods (PHYS-205) or permission from department."

K. Nordstrom  
*Prereq: Quantum Mechanical Phenomena (PHYS-250)."

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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 along side of basic engineering principles through project/case studies.

*Crosslisted as: CHEM-328*

*Applies to requirement(s): Writing-Intensive*

M. Gomez  
*Prereq: MATH-102 and PHYS-201.*

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PHYS-329 Advanced Physics  
*PHYS-336 Quantum Mechanics  
*Spring. 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."

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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*

The department  
*Instructor permission required.*

*Notes: Repeatable for credit."

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

The department  
*Instructor permission required."

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

The department  
*Instructor permission required."

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The department  
*Instructor permission required."

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Notes: Repeatable for credit.