

# PHYSICS (PHYS)

## 100 Level Courses

**PHYS 103:** *Physics and Everyday Phenomena I.* 4 credits.

The course uses basic physics concepts from the areas of mechanics and thermodynamics to explain a wide range of everyday phenomena, such as how we walk and drive, how a ship floats, how clothing keeps us warm, and why it rains when we have a low pressure system. Notes: For nonscience majors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Schedule Type:** Laboratory, Lecture

### Grading:

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 104:** *Physics and Everyday Phenomena II.* 4 credits.

The course uses basic physics concepts from the areas of light, sound, electricity, magnetism, and modern physics to explain a wide range of everyday phenomena. Topics include how we speak, hear, and see, what to do if the circuit breaker keeps tripping, how your computer stores and displays data, how rainbows and northern lights form, and the basic nature of matter. Notes: For nonscience majors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Recommended Prerequisite:** PHYS 103.

**Schedule Type:** Laboratory, Lecture

### Grading:

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 106:** *The Quantum World: A Continuous Revolution in What We Know and How We Live.* 3 credits.

This course presents quantum physics that revolutionized the 20th Century and continues to evolve. In addition to presenting basic concepts, the course will discuss various applications involving quantum phenomena including quantum computers and quantum teleportation. The course will be a historical journey through the quantum science that many of its founders, such as Einstein, could not accept, and a peek into a possible future. Notes: For non-science majors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Schedule Type:** Lecture

### Grading:

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 111:** *Introduction to the Fundamentals of Atmospheric Science.* 3 credits.

An overview of the Earth's atmosphere, its history, and the physical and chemical processes that determine its characteristics. The focus is on key concepts from thermodynamics, radiation, chemistry, and dynamics that are essential for understanding the state, variability, and long term evolution of the atmosphere, especially in the context of comparisons with other planetary atmospheres. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to CLIM 111.

**Mason Core:** Mason Core (All), Natural Science Overview, Encore: Sustainability (<http://catalog.gmu.edu/mason-core/>)

**Specialized Designation:** Green Leaf Related Course

**Schedule Type:** Lecture

### Grading:

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 112:** *Introduction to the Fundamentals of Atmospheric Science Lab.* 1 credit.

Laboratory course associated with PHYS 111/CLIM 111. Study of the Earth's atmosphere based on concepts taken from thermodynamics, radiation transport, chemistry, and dynamics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to CLIM 112.

**Mason Core:** Mason Core (All), Natural Science with Lab, Encore: Sustainability (<http://catalog.gmu.edu/mason-core/>)

**Specialized Designation:** Green Leaf Related Course

### Registration Restrictions:

**Required Prerequisites:** (PHYS 111<sup>\*C</sup>, CLIM 111<sup>\*C</sup>, PHYS 111<sup>XS</sup> or CLIM 111<sup>XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

### Grading:

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 122:** *Inside Relativity.* 1 credit.

Introductory course describing Einstein's theories of special and general relativity. Notes: Intended for majors and nonmajors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Schedule Type:** Lecture

### Grading:

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 123:** *Inside the Quantum World.* 1 credit.

Introductory course describing quantum theory. Notes: Intended for majors and nonmajors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 124:** *Experimental Explorations in Physics*. 2 credits.

Introductory nonmathematical course intended primarily for physics majors. Experimental studies of phenomena in mechanics, electricity and magnetism, and optics. Stresses development of familiarity with methods and techniques of measurement and with data evaluation. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 131:** *Introduction to Renewable Energy*. 3 credits.

An overview of the renewable-energy field suitable for all students regardless of major. Topics include renewable-energy technologies, trends in the adoption of renewable energy, successful policy drivers, and environmental impacts. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to RENE 131.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 160:** *University Physics I*. 3 credits.

First semester of three-semester, calculus-based introductory physics sequence, designed primarily for science and engineering majors. Mechanics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to PHYS 170.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** MATH 114<sup>\*C</sup>, 114<sup>XS</sup>, 116<sup>\*C</sup> or 116<sup>XS</sup>.

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 161:** *University Physics I Laboratory*. 1 credit.

Experiments in mechanics, including techniques for recording, graphically and statistically analyzing, and reporting data. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 160<sup>\*C</sup>, 160<sup>XS</sup>, 170<sup>\*C</sup> or 170<sup>XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 170:** *Introductory and Modern Physics I*. 3 credits.

The first of a two-course, calculus-based introductory physics sequence. Topics include conservation laws, special relativity, quantum physics, thermal physics, Newton's laws, and electromagnetism. PHYS 170 does not satisfy the prerequisite for PHYS 260. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to PHYS 160.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** MATH 113<sup>\*C</sup> or 113<sup>XS</sup>.

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 200 Level Courses

**PHYS 225:** *Problems in Physics I*. 1-3 credits.

Individual study of physics problems of current interest. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 3 credits.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Independent Study

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 243:** *College Physics I*. 3 credits.

The first of a two-semester algebra-based physics sequence with emphasis on topics of classical and modern physics of particular importance to science majors. Topics include principles of mechanics and heat. Facility in algebra and trigonometry is assumed. PHYS 243 is prerequisite to PHYS 245. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 244:** *College Physics I Lab*. 1 credit.

Laboratory portion of two-semester basic physics course. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** PHYS 243<sup>C</sup> or 243<sup>XS</sup>.

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 245:** *College Physics II*. 3 credits.

The second of a two-semester algebra-based physics sequence with emphasis on topics of classical and modern physics of particular importance to science majors. Topics include principles of electricity, magnetism, optics, and atomic and nuclear physics. Facility in algebra and trigonometry is assumed. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** PHYS 243<sup>C</sup> or 243<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 246:** *College Physics II Lab*. 1 credit.

Laboratory portion of two-semester basic physics course. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** PHYS 244<sup>C</sup> or 244<sup>XS</sup> and PHYS 245<sup>\*C</sup> or 245<sup>XS</sup>.

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 251:** *Introduction to Computer Methods in Physics*. 3 credits.

Introduction to using computers in physics based on examples from mechanics and astronomy. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Info Tech & Computing (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** PHYS 160<sup>C</sup>, 160<sup>XS</sup> or 170<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 260:** *University Physics II*. 3 credits.

Waves, electricity, and magnetism. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to PHYS 270.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 160<sup>C</sup> or 160<sup>XS</sup>) and (MATH 213<sup>\*C</sup>, 213<sup>\*XS</sup>, 215<sup>\*C</sup> or 215<sup>\*XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 261:** *University Physics II Laboratory*. 1 credit.

Experiments in mechanics, electricity, and magnetism, including techniques for recording, graphically and statistically analyzing, and reporting data. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** ((PHYS 161<sup>C</sup> or 161<sup>XS</sup>) and (PHYS 260<sup>\*C</sup>, 260<sup>XS</sup>, 270<sup>\*C</sup> or 270<sup>XS</sup>)).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 262:** *University Physics III*. 3 credits.

Thermodynamics, optics, and modern physics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Recommended Prerequisite:** C or higher in PHYS 261.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 260<sup>C</sup> or 260<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 263:** *University Physics III Laboratory*. 1 credit.

Experiments in optics and modern physics, including techniques for recording, graphically and statistically analyzing, and reporting data. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Natural Science with Lab (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 261<sup>C</sup> or 261<sup>XS</sup>) and (PHYS 262<sup>\*C</sup> or 262<sup>XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 266:** *Introduction to Thermodynamics*. 1 credit.

Students may not receive credit for both PHYS 262 and 266. Laws of thermodynamics, kinetic theory of gases, heat engines, and entropy. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 260<sup>C</sup> or 260<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 270:** *Introductory and Modern Physics II*. 3 credits.

The second of a two-course, calculus-based introductory physics sequence. Topics include conservation laws, special relativity, quantum physics, thermal physics, Newton's laws, and electromagnetism. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to PHYS 260.

**Mason Core:** Mason Core (All), Natural Science Overview (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** PHYS 170<sup>C</sup> and (MATH 114<sup>\*C</sup> or 114<sup>XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

### 300 Level Courses

**PHYS 301:** *Analytical Methods of Physics*. 3 credits.

Analytical methods in the Physical Sciences. Provides a comprehensive introduction to the areas of mathematical physics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** MATH 214<sup>C</sup> or 214<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 303:** *Classical Mechanics*. 3 credits.

Motion of a particle in one, two, and three dimensions; systems of particles; noninertial coordinate systems; and equations of Lagrange and Hamilton. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>) and (PHYS 301<sup>\*C</sup> or 301<sup>\*XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 305:** *Electromagnetic Theory*. 3 credits.

Interaction of static charges, interaction of stationary currents, electromagnetic induction, and Maxwell's equations. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>) and (PHYS 301<sup>\*C</sup> or 301<sup>\*XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 306:** *Wave Motion and Electromagnetic Radiation*. 3 credits.

Vibrating string, plane waves, interference, diffraction, polarization, electromagnetic waves, dispersion, and relativity. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** ((PHYS 305<sup>C</sup> or 305<sup>XS</sup>) and (PHYS 301<sup>C</sup> or 301<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 307: Thermal Physics.** 3 credits.

Classical concepts of energy and temperature, basic definitions, first and second laws of thermodynamics, properties of pure substances, and equations of state. Introduction to classical and quantum statistics and their application to physical systems. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 308: Modern Physics.** 3 credits.

Introduces relativity, quantum mechanics, and selected topics in modern physics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 310: Physics of Semiconductor Materials and Processing.** 3 credits.

Survey of the electronic and structural properties of semiconductors and the physics of semiconductor processing. Topics to be discussed include crystal growth, crystal defects, thin films, thermal properties, lithography, and characterization. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 262<sup>C</sup>, 262<sup>XS</sup>, 307<sup>C</sup> or 307<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 311: Instrumentation.** 3 credits.

Introduction to basic analog and digital circuits, circuit design and simulation, and data acquisition. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 261<sup>C</sup> or 261<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory, Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 312: Waves and Optics.** 3 credits.

Laboratory survey of wave and optical phenomena and associated instrumentation. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 261<sup>C</sup> or 261<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory, Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 325: Intermediate Computer Methods in Physics.** 3 credits.

Computer-based modeling and data analysis of experiments in mechanics, electromagnetism, and optics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 261<sup>C</sup> or 261<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 326: Problems in Physics II.** 1-3 credits.

Individual study of physics problems of current interest. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 3 credits.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 301<sup>\*C</sup>, 301<sup>\*XS</sup>, 307<sup>\*C</sup> or 307<sup>\*XS</sup>.

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Independent Study

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 331: *Physics of Renewable Energy*.** 3 credits.

Introduces the physical principles for a range of renewable energies, including solar, wind, hydropower and geothermal. Demonstrates how the application of methods and principles of physics allow us to understand the basic operation, advantages, limitations and relative merits of various renewable energy sources. Designed for students majoring in the sciences or engineering but useful for students interested in science policy, business, global change and sustainable development. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Specialized Designation:** Green Leaf Related Course

**Registration Restrictions:**

**Required Prerequisites:** PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 332: *Solar Cells*.** 3 credits.

Covers the physics of solar cells, basics of semiconductors, pn junctions, basic structure of solar cells, the latest advances in solar cell materials, and concepts for improving the efficiency of solar cells. Solar cell design based on silicon, copper indium gallium selenide, gallium arsenide, organic solar cells, dye-sensitized solar cells, quantum dots, and nanowires will also be reviewed. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Specialized Designation:** Mason Impact.

**Registration Restrictions:**

**Required Prerequisites:** ((PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>) and (PHYS 261<sup>C</sup> or 261<sup>XS</sup>)) or ((PHYS 245<sup>C</sup> or 245<sup>XS</sup>) and (PHYS 246<sup>C</sup> or 246<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 334: *Introduction to Quantum Computation and Quantum Information*.** 3 credits.

Introduction to the basic components of quantum computing (qubit, quantum gates, and quantum circuits, entanglement, the non-cloning theorem, dense coding, and quantum teleportation, including physical implementation), as well as quantum algorithms, such as Deutsch-Josza, Bernstein-Varirani, Simon's, Shor's, and Grover's algorithms, and quantum error correction code. Quantum coding of these algorithms will be run on an IBMq. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 260<sup>C</sup>, 260<sup>XS</sup> or 270<sup>C</sup>) and ((MATH 203<sup>C</sup> or 203<sup>XS</sup>) or (PHYS 301<sup>C</sup> or 301<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 346: *Quarks to Strings*.** 3 credits.

An non-technical introduction to the Standard Model of Elementary Particles and String Theory, in the context of the philosophy of science. Conceptual mastery will be demonstrated through writing assignments rather than calculations. Notes: This course does not satisfy elective-category requirements for the physics and astronomy majors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Mason Apex (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** PHYS 262<sup>C</sup>, 262<sup>XS</sup>, 270<sup>C</sup>, 308<sup>C</sup> or 308<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 370: *Molecular Biophysics*.** 3 credits.

Offers a broad introduction into molecular biophysics. Demonstrates that the application of methods of physics provides a unique opportunity to tackle complex biological programs. Mainly designed for students majoring in physics or chemistry but also useful for biology majors interested in bioinformatics and computational biology. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to BINF 470.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 307<sup>C</sup> or 307<sup>XS</sup>) or ((CHEM 331<sup>C</sup> or 331<sup>XS</sup>) and (CHEM 332<sup>C</sup> or 332<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 385: *Materials Science with Applications to Renewable Energy*.** 3 credits.

Introduction to basic concepts and methods of materials science. Review of metallic alloys and compounds, ceramic materials, ionic solids, semiconductors, polymers, and nano-structured materials. Mechanical, thermal, electric, magnetic and optical properties of materials. Theoretical background and experimental methods of materials characterization. Various materials applications with emphasis on renewable energy. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Specialized Designation:** Green Leaf Related Course

**Registration Restrictions:**

**Required Prerequisites:** PHYS 262<sup>C</sup>, 262<sup>XS</sup>, 266<sup>C</sup>, 266<sup>XS</sup>, 307<sup>C</sup>, 307<sup>XS</sup>, ME 221<sup>C</sup> or 221<sup>XS</sup> or ((PHYS 245<sup>C</sup> or 245<sup>XS</sup>) and (MATH 113<sup>C</sup> or 113<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.  
<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 390:** *Topics in Physics*. 1-4 credits.

Selected topics in physics not covered in fixed-content courses. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the term for a maximum 9 credits.

**Specialized Designation:** Topic Varies

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 391:** *Special Topics in Physics*. 1-4 credits.

Special topics in physics not covered in fixed-content courses. Notes: This course does not satisfy elective-category requirements for the physics or astronomy majors. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the term for a maximum 9 credits.

**Specialized Designation:** Topic Varies

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 400 Level Courses

**PHYS 402:** *Introduction to Quantum Mechanics and Atomic Physics*. 3 credits.

Experimental basis of quantum mechanics; the wave function; systems in one, two, and three dimensions. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts. Equivalent to PHYS 502.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 403:** *Quantum Mechanics II*. 3 credits.

Additional topics in Quantum Mechanics: angular momentum, perturbation theory, scattering, and the Dirac Equation. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 402<sup>C</sup> or 402<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 405:** *Honors Thesis in Physics I*. 3 credits.

Project chosen and completed under the guidance of a faculty member, which results in a thesis. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Notes: PHYS 405 is a prerequisite for PHYS 406. An oral progress report is required for PHYS 405. Oral and written presentations are required for PHYS 406. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 301<sup>C</sup> or 301<sup>XS</sup>) and (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>) and (PHYS 307<sup>C</sup> or 307<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment is limited to students with a major in Physics.

**Schedule Type:** Independent Study

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 406:** *Honors Thesis in Physics II*. 3 credits.

Project chosen and completed under the guidance of a faculty member, which results in a thesis. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Notes: PHYS 405 is a prerequisite for PHYS 406. An oral progress report is required for PHYS 405. Oral and written presentations are required for PHYS 406. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisite:** PHYS 405<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

**Schedule Type:** Independent Study

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 407:** *Senior Laboratory in Modern Physics*. 4 credits.

Advanced experiments in modern physics: electronics, optics, condensed matter, and nuclear physics. Techniques for recording, graphically and statistically analyzing, and reporting data. Typical experiments include the Frank-Hertz experiment, Hall Effect, electron spin resonance, nuclear magnetic resonance and optical pumping. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Mason Apex (<http://catalog.gmu.edu/mason-core/>)

**Specialized Designation:** Writing Intensive in Major

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 311<sup>C</sup> or 311<sup>XS</sup>) and (PHYS 312<sup>C</sup> or 312<sup>XS</sup>) and (PHYS 402<sup>C</sup> or 402<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 408: Senior Research.** 2-3 credits.

Work under guidance of faculty member on research project in experimental or theoretical physics. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Notes: May be repeated with permission of the Physics Department. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 6 credits.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 301<sup>C</sup> or 301<sup>XS</sup>) and (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>) and (PHYS 307<sup>C</sup> or 307<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Research

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 409: Physics Internship.** 3 credits.

On-the-job experience for physics majors in industry or government laboratories including summer programs. Notes: May be repeated with permission of the Department of Physics & Astronomy. Students may receive no more than 6 credits of PHYS 405, 406, 408, and 409. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 6 credits.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 301<sup>C</sup> or 301<sup>XS</sup>) and (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>) and (PHYS 307<sup>C</sup> or 307<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Internship

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 410: Computational Physics Capstone.** 4 credits.

Applications of computational techniques to simulate, visualize, and solve numerically problems from a variety of physical systems. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Mason Core:** Mason Core (All), Mason Apex (<http://catalog.gmu.edu/mason-core/>)

**Specialized Designation:** Writing Intensive in Major

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 251<sup>C</sup> or 251<sup>XS</sup>) and (PHYS 325<sup>C</sup> or ASTR 401<sup>C</sup>) and (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Laboratory, Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 411: Renewable Energy Internship.** 3 credits.

On-the-job experience for Renewable Energy minors in industry, government, or non-profit organizations, including Summer programs. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to two attempts. Equivalent to RENE 411.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 131<sup>C</sup> or 131<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Internship

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 412: Solid State Physics and Applications.** 3 credits.

Crystal structures, binding, lattice vibrations, the free electron model, metals, semiconductors and semiconductor devices, superconductivity, and magnetism. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 402<sup>C</sup>, 402<sup>XS</sup>, 502<sup>B-</sup> or 502<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

<sup>B-</sup> Requires minimum grade of B-.

**Schedule Type:** Laboratory, Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 416: Undergraduate Physics Review.** 1 credit.

Emphasizing the breadth of physical understanding needed to approach physics problems, the course reviews undergraduate physics through assigned, GRE test-like, problems. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 301<sup>C</sup> or 301<sup>XS</sup>) and (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>) and (PHYS 307<sup>C</sup> or 307<sup>XS</sup>) and (PHYS 402<sup>C</sup> or 402<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 417: Geophysics.** 3 credits.

Basic principles of geophysics including gravity, magnetism, and seismic reflection and refraction. Offered by Physics & Astronomy (<http://catalog.gmu.edu/policies/academic/grading/>)



catalog.gmu.edu/colleges-schools/science/physics-astronomy/). Limited to three attempts. Equivalent to GEOL 417.

**Recommended Prerequisite:** GEOL 101 and GEOL 103, MATH 113, and one year of PHYS, or permission of instructor.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 428: Relativity.** 3 credits.

Special relativity; four-dimensional space-time; general relativity; non-Euclidean geometries, geodesics, and field equations; tests of general theory of relativity; black holes; cosmology; models of the universe; remnant blackbody radiation; big bang cosmology; thermodynamics; and the universe. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 303<sup>C</sup> or 303<sup>XS</sup>) and (PHYS 305<sup>C</sup> or 305<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 440: Nuclear and Particle Physics.** 3 credits.

Accelerators, detectors and related electronics; nuclear and elementary particle structure; symmetries and conservation laws; the electromagnetic, weak, and hadronic interactions; nuclear models; the quark model; and nuclear science and technology. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 402<sup>C</sup>, 402<sup>XS</sup>, 502<sup>B-</sup> or 502<sup>XS</sup>) and (PHYS 428<sup>\*C</sup> or 428<sup>\*XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

<sup>B-</sup> Requires minimum grade of B-.

**Schedule Type:** Laboratory, Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 465: Planetary Atmospheres and Ionospheres.** 3 credits.

An interdisciplinary introduction to the fundamental physics and chemistry of the atmosphere-ionosphere system. The focus is on the governing equations of atmospheric and ionospheric dynamics with a systems (science) approach to the atmosphere-ionosphere coupling processes. Topics include observational and modeling techniques in the Earth's upper atmosphere as well as recent progress in planetary atmosphere-ionospheres and planetary missions. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 260<sup>C</sup> or 260<sup>XS</sup>) and (PHYS 301<sup>C</sup> or 301<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 475: Atmospheric Physics.** 3 credits.

Introduction to basic physical and chemical processes that operate in the Earth's atmosphere. Emphasis on those concepts that provide a global description of the current atmospheric state and those processes that relate to global change and atmospheric evolution. Topics include equilibrium structure, radiative transfer models, thermodynamics of various atmospheric layers, and the various processes defining these layers. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 170<sup>C</sup>, 262<sup>C</sup>, 262<sup>XS</sup>, 307<sup>C</sup> or 307<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 500 Level Courses

**PHYS 502: Introduction to Quantum Mechanics and Atomic Physics.** 3 credits.

Experimental basis of quantum mechanics, the wave function, and systems in one, two, and three dimensions. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 308 or the equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 510: Computational Physics I.** 3 credits.

Study and development leading to computer simulations of various physical systems. Requires the study and development of computational techniques and numerical algorithms to obtain both numerical results and visualization of these results. Application to individual physical processes taking place in a variety of physical systems. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 512: *Solid State Physics and Applications*.** 3 credits. Crystal structures, binding, lattice vibrations, the free electron model, metals, semiconductors and semiconductor devices, superconductivity, and magnetism. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 402 or PHYS 502 or the equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 513: *Applied Electromagnetic Theory*.** 3 credits. Classical electromagnetic theory with applications. Topics include electrostatics, magnetic fields and materials, electromagnetic wave propagation, waveguides, transmission lines, radiation, and antennas. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 533: *Modern Instrumentation*.** 3 credits. Topics include sensors for radiation, particles, electric and magnetic fields, pressure, and motion; electronic instruments, computer data collection, instrumentation noise and noise reduction methods; and specialized instrumentation systems for various areas of applied physics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit. Equivalent to CHEM 620.

**Recommended Prerequisite:** PHYS 513 or PHYS 685

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 534: *Introduction to Quantum Computation and Quantum Information*.** 3 credits.

This course introduces science and engineering students to quantum computing code and quantum information using a linear algebra based approach. Prior experience with quantum mechanics is not required. Over the semester counterintuitive concepts, such as quantum entanglement and quantum teleportation, will be demystified. Basic quantum algorithms will be analyzed to understand quantum speedup over classical computing. Hands-on training in quantum circuit design and writing quantum code will be provided, culminating in running this code on simulators and quantum computers. Course content will include distinctions between classical and quantum computing, the qubit, quantum gates and circuits, and quantum algorithms for query, data base search, factorization, and error correction. State of the art and future prospects of quantum technology will also be discussed. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** Experience with programming. MATH 203 or PHYS 301. PHYS 160, 260; or 170, 270; or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Post-Baccalaureate or Non-Degree Undergraduate degrees may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 540: *Nuclear and Particle Physics*.** 3 credits. Accelerators, detectors and related electronics; nuclear and elementary particle structure; symmetries and conservation laws; the electromagnetic, weak, and hadronic interactions; nuclear models; the quark model; and nuclear science and technology. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 402 or PHYS 502, or the equivalents.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 575: Atmospheric Physics.** 3 credits.

Introduction to basic physical and chemical processes that operate in the Earth's atmosphere. Emphasis on those concepts that provide a global description of the current atmospheric state and those processes that relate to global change and atmospheric evolution. Topics include equilibrium structure, radiative transfer models, thermodynamics of various atmospheric layers, and the various processes defining these layers. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 305, PHYS 262, and PHYS 260, or the equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 580: Selected Interdisciplinary Topics.** 3 credits.

Selected interdisciplinary topics with a strong physics content not covered in fixed-content courses. Notes: PHYS 580 cannot be used to satisfy degree requirements for PHYS (PhD), PHAE (MA) in the standard, applied physics, and engineering physics emphases. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 581: Topics in Renewable Energy.** 3 credits.

The course covers the physical principles for a range of renewable energies, including solar, wind, hydropower, and geothermal using mathematical and other types of analysis. The course demonstrates how the application of methods and principles of physics allow us to understand the basic operation, advantages, limitations, and relative merits of various renewable energy sources. Offered by Physics &

Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Specialized Designation:** Topic Varies

**Recommended Prerequisite:** PHYS 262 and PHYS 266, or the equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 590: Selected Topics in Physics.** 1-6 credits.

Selected topics from recent theoretical or experimental developments and applications. Satisfies needs of professional community to keep abreast of current developments. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the term for a maximum 6 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 591: Systems for Quantum Scientists.** 3 credits.

This course will introduce students to real world problem solving in quantum information science and engineering using the principles of system architecture. These principles are useful to students independent of career path, but particularly important for a successful transition into a career in industry. Students will work together on teams to identify a scientific or technical challenge in quantum science and engineering. Key activities will include weekly meetings to plan and discuss key aspects of their challenge, meetings with industry experts regarding the principles of systems architecture, and designing a solution to their challenge. The report on the project design will be submitted in stages and will include a motivation, approach, detailed technical schematics, cost estimation, risk assessment, and risk mitigation strategies. The report will be evaluated by GMU faculty and industrial experts, and there will be a 'pitch' style presentation as part of the final project. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 600 Level Courses

**PHYS 600:** *Special Topics in Physics*. 1-6 credits.

In-service course to strengthen and update teachers' knowledge of physics and astronomy. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the term.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 611:** *Electro-optics*. 3 credits.

Optical modulators, display devices, types and operation of lasers, mode locking, Q-switching, photodetectors, optical fibers. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** ((PHYS 502<sup>B-</sup>, 502<sup>XS</sup>, 684<sup>B-</sup> or 684<sup>XS</sup>) and (PHYS 513<sup>B-</sup>, 513<sup>XS</sup>, 685<sup>B-</sup> or 685<sup>XS</sup>)).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 612:** *Physics of Modern Imaging*. 3 credits.

Study of imaging methods using acoustic and electromagnetic waves to probe extended objects, and mathematical transformations to produce images from scattered waves. Topics include classical imaging, physical optics, Fourier transform, holography, tomography, seismic mapping, underwater acoustic imaging and mapping, side-looking radar, antenna arrays, applicable computer methods. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 513<sup>B-</sup>, 513<sup>XS</sup>, 685<sup>B-</sup> or 685<sup>XS</sup>).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 613:** *Computational Physics II*. 3 credits.

Study of diverse physical systems with emphasis on modeling and simulation. Study and development of numerical algorithms and techniques to obtain both numerical results and visualization of these results. Projects undertaken will draw from such areas as many-body orbital dynamics, molecular interactions, quantum systems, radiative transfer in high-temperature plasmas, stellar interiors, hydrodynamics, and cosmology. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 510

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 614:** *Thermodynamics and Kinetics of Materials*. 3 credits.

Advanced thermodynamics and physical kinetics with applications to materials science. The course covers an axiomatic formulation of thermodynamics, theory of phase transformations, kinetic theory of reactions and diffusion processes in solids, and interface phenomena. Possible applications considered in the course include processing and fabrication of semiconductor materials, metal oxidation and corrosion, diffusion-controlled phase growth in solid solutions, shape memory alloys, and small-size effects in physical properties of materials. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 113<sup>C</sup> or 113<sup>XS</sup>) and (MATH 114<sup>C</sup> or 114<sup>XS</sup>) and (MATH 213<sup>C</sup> or 213<sup>XS</sup>) and MATH 307<sup>C</sup> and (PHYS 262<sup>C</sup>, 262<sup>XS</sup>, 266<sup>C</sup> or 266<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 615: *Fundamentals of Materials Science*.** 3 credits.

Covers fundamentals of materials science with emphasis on physical topics including crystal structure and symmetry, dislocation theory, theory of interfaces, multicomponent phase diagrams, theory of phase transformations, nano-materials, metallic glasses. Includes a term project, assignments from current literature and application of computation in materials science. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit. Equivalent to CSI 685.

**Recommended Prerequisite:** CDS 385 or PHYS 385 or undergraduate degree in physics, chemistry, materials, electrical or mechanical engineering or related disciplines; or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 620: *Continuum Mechanics*.** 3 credits.

Study of continuum mechanics; topics include physical concepts, mathematical formulation and solution, elastic materials, ideal fluids, viscous fluids, waves in continuous media, turbulence, thermal convection, stability considerations, high-temperature gas flows, radiative processes for momentum and energy transport, shocks, and computational fluid dynamics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 628: *Relativity*.** 3 credits.

Special relativity; four-dimensional space-time; general relativity; non-Euclidean geometries, geodesics, and field equations; tests of general theory of relativity; black holes; cosmology; models of the universe; remnant blackbody radiation; big bang cosmology; thermodynamics; and the universe. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 303, 305, or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 630: *Introduction to Biophysics*.** 3 credits.

Introduces biophysics, focusing on physical and chemical concepts and their relation to rapidly expanding interdisciplinary interfaces among biology, chemistry, and physics. Reveals multiscale nature of biophysics, and includes exploration of macroscopic and microscopic applications. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit. Equivalent to BINF 740.

**Recommended Prerequisite:** Undergraduate degree in physics, or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 640: *Finite Element Analysis of Solids and Fluids*.** 3 credits.

Introduction to fundamentals of finite element analysis of solid, structural, fluid, and heat transfer problems. Topics include governing equations for heat transfer, solid and fluid mechanics; finite element formulation and solution procedures; appropriate use of finite element methods including setting up an appropriate model, interpreting results, and assessing solution error. Students are expected to develop their own finite element code. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 620 or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 660:** *Space Weather*. 3 credits.

Overview of space weather, including topics such as the sun, heliosphere, magnetosphere, and ionosphere. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit. Equivalent to ASTR 660.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 665:** *Planetary Atmospheres and Ionospheres*. 3 credits.

An interdisciplinary introduction to the fundamental physics and chemistry of the atmosphere-ionosphere system. The focus is on the governing equations of atmospheric and ionospheric dynamics with a systems (science) approach to the atmosphere-ionosphere coupling processes. Topics include observational and modeling techniques in the Earth's upper atmosphere as well as recent progress in planetary atmosphere-ionospheres and planetary missions. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 262, MATH 214.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 683:** *Mathematical Methods in Physics*. 3 credits.

Covers common mathematical methods used in physics. Topics include vector and variational calculus; functions of complex variables; integral and discrete transforms; ordinary and partial differential equations; special functions; and linear operators and matrices. Offered by Physics

& Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** Undergraduate degree in physics or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 684:** *Quantum Mechanics I*. 3 credits.

Fundamental concepts of quantum mechanics, including Dirac notation, quantum dynamics, theory of angular momentum, and symmetries. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to students with a major in Applied Engineering Physics or Physics.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 685:** *Classical Electrodynamics I*. 3 credits.

Deals with static and dynamic properties of electromagnetic fields as described by Maxwell's equations. Covers electrostatics, magnetostatics, boundary value problems, multipoles, time dependent fields, propagating wave solutions, and resonant structures. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to students with a major in Applied Engineering Physics or Physics.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 690: *Engineering Thermodynamics*.** 3 credits.

Introduction to the basic concepts used in engineering when dealing with thermodynamic problems. Topics include equations of state, phase changes, latent heat, internal energy, enthalpy, entropy, and analysis of basic thermodynamic cycles such as Carnot cycles, power generation, internal combustion engines and refrigeration processes. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 620 or PHYS 705 or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 694: *Applied Mechanics of Solids*.** 3 credits.

Introduction to the physical laws, mathematical formulations, and computer algorithms that are used to predict material and structural response subjected to mechanical or thermal loading. Topics covered includes mathematical description of solids, equations of motion and equilibrium, constitutive equations, principle of virtual work, and fracture mechanics. Analytical technique and numerical method are also covered. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 620

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 695: *Applied Fluid Mechanics*.** 3 credits.

Introduction to concepts of fluid mechanics and solving its equations using numerical techniques. The concepts and methods of computational fluid dynamics (CFD) will be introduced. Topics include fluid mechanics equations, spatial and temporal discretization, finite difference and finite volume schemes, accuracy and convergence. This course requires writing of code to solve the governing equations of fluid mechanics. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** PHYS 620 or PHYS 705 or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**700 Level Courses****PHYS 701: *Theoretical Physics*.** 3 credits.

Study of the physical basis for selection of particular mathematical tools in physics; topics include curvilinear coordinates, tensors, matrices, differential equations, special functions, complex variables, and group theory. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** Undergraduate degree in physics or permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 703: *Seminar in Physics*.** 1 credit.

A general seminar course that combines invited seminars from faculty (both internal and external) with graduate student seminars. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 6 credits.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Seminar

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 705: *Classical Mechanics*.** 3 credits.

Study of classical mechanics; topics include variational principles, constrained motion, Lagrangian and Hamiltonian mechanics, canonical transformations, and applications (central forces, rigid-body motion, oscillations). Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** Undergraduate degree in physics or permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 711: *Statistical Mechanics*.** 3 credits.

Topics include thermodynamics, kinetic theory, ensemble theory, quantum statistics, and applications. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Recommended Prerequisite:** Undergraduate degree in physics or permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 736: *Computational Quantum Mechanics*.** 3 credits.

Study of the fundamental concepts of quantum mechanics from a computational point of view, review of systems with spherically symmetric potentials, many-electron-atom solutions to Schrodinger's equation, electron spin in many-electron systems, atomic structure calculations, algebra of many-electron calculations, Hartree-Fock self-consistent field method, molecular structure calculations, scattering theory computations, and solid-state computations. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit. Equivalent to CHEM 736, CSI 783.

**Registration Restrictions:**

**Required Prerequisites:** ((PHYS 502<sup>B-</sup> or 502<sup>XS</sup>) and (PHYS 510<sup>B-</sup> or 510<sup>XS</sup>)).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 760: *Space Plasma Physics*.** 3 credits.

Covers plasma processes involved in today's space physics research, including different regimes of plasma; basic concepts in kinetic, fluid, and MHD plasmas; and existent waves in these media. Also covers basics of shocks, discontinuities, transport and acceleration of particles such as cosmic rays, reconnection, and MHD instabilities. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 513<sup>B-</sup>, 513<sup>XS</sup>, 685<sup>B-</sup> or 685<sup>XS</sup>).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 780: *Advanced Selected Topics in Physics*.** 3 credits.

Selected topics in physics not covered in fixed-content physics courses. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the term for a maximum 6 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 784: *Quantum Mechanics II*.** 3 credits.

Advanced topics in quantum mechanics. Covers density and tensor operators, approximation methods, scattering theory, and identical particles. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 684<sup>B-</sup> or 684<sup>XS</sup>).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 785: *Classical Electrodynamics II*.** 3 credits.

Advanced topics in electrodynamics. Covers radiation, scattering and diffraction, special relativity, relativistic particle dynamics, Lorentz transformation, 4-vectors, transformation of fields, charges and currents, Thomas precession, retarded potentials, and radiation from moving charges. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** PHYS 685<sup>B-</sup> or 685<sup>XS</sup>.

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.



Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 786: *Quantum Field Theory of Particles and Condensed Matter.*** 3 credits.

Introduction to quantum field theory and its applications in particle and condensed matter physics. Topics: second quantization, scalar bosonic and fermionic fields, symmetries and conserved currents, Dirac equation, gauge theory, quantum electrodynamics, Feynman diagrams, renormalization, Fermi liquid, symmetry breaking, superconductivity, magnetism, path integral, quantum phase transitions to topological order, etc. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 6 credits.

**Registration Restrictions:**

**Required Prerequisites:** (PHYS 684<sup>B-</sup> or 684<sup>XS</sup>).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 794: *Physics Internship.*** 1-6 credits.

In collaboration with an external company or research lab in a physics related field, this internship course provides students with hands-on experience in an applied setting. Students will be able to apply their academic and research skills acquired in their courses in a real professional environment with a goal to enhance their career and job opportunities. This course will be co-managed by a GMU faculty course instructor and a project supervisor from the external company or research lab. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 6 credits.

**Recommended Prerequisite:** Departmental approval

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate or Non-Degree.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Internship

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 796: *Directed Reading and Research.*** 1-12 credits.

Reading and research on a specific topic in physics or related field under the direction of a faculty member. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree.

**Recommended Prerequisite:** Admission to MS or PhD program and permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Research

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 798: *Research Project.*** 3 credits.

Research project chosen and completed under the guidance of a graduate faculty member resulting in an acceptable technical report. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 6 credits.

**Recommended Prerequisite:** Nine graduate credits or permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Thesis

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 799: *Master's Thesis.*** 1-6 credits.

Project chosen and completed under the guidance of a graduate faculty member, which results in an acceptable technical report and oral defense. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree.

**Recommended Prerequisite:** 9 graduate credits, and permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Thesis

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 900 Level Courses

**PHYS 998: *Doctoral Dissertation Proposal.*** 1-12 credits.

Covers development of a research proposal under the guidance of a dissertation director and the doctoral committee. The proposal forms the basis for the doctoral dissertation. Notes: No more than 24 credits in ASTR/PHYS 998 and ASTR/PHYS 999 may be applied toward satisfying doctoral degree requirements in the physics PhD program. Out of the 24, no more than 12 credits of ASTR/PHYS 998 may be applied. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 21 credits.

**Recommended Prerequisite:** Admission to physics doctoral program and permission of advisor.

**Schedule Type:** Dissertation

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**PHYS 999: *Doctoral Dissertation*.** 1-12 credits.

Doctoral research performed under direction of dissertation director.

Notes: No more than 24 credits in ASTR/PHYS 998 and ASTR/PHYS 999 may be applied toward satisfying doctoral degree requirements in the physics PhD program. Offered by Physics & Astronomy (<http://catalog.gmu.edu/colleges-schools/science/physics-astronomy/>). May be repeated within the degree for a maximum 24 credits.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy.

Enrollment is limited to Graduate level students.

**Schedule Type:** Dissertation

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)