

## PHYSICS (Div III)

Chair: Professor David Tucker-Smith

- Daniel P. Aalberts, Kennedy P. Richardson '71 Professor of Physics; affiliated with: Physics & Astronomy, BiGP (Bioinformatics, Genomics, and Proteomics)
- Charlie Doret, Associate Professor of Physics; on leave Spring 2025
- Kevin Flaherty, Lecturer in Astronomy and Observatory Supervisor
- Graham K. Giovanetti, Assistant Professor of Physics
- Anne Jaskot, Assistant Professor of Astronomy and Associate of the Hopkins Observatory
- Katharine E. Jensen, Associate Professor of Physics
- Catherine Kealhofer, Assistant Professor of Physics
- Protik K. Majumder, Barclay Jermain Professor of Natural Philosophy
- Betül Pamuk, Assistant Professor of Physics
- Frederick W. Strauch, William Edward McElfresh Professor of Physics
- David R. Tucker-Smith, Chair
- Jason E. Young, Visiting Field Memorial Assistant Professor of Astronomy

What is light? How does a laser work? What is a black hole? What are the fundamental building blocks of the universe? Physics majors and Astrophysics majors study these and related questions to understand the physical world around us, from the very small to the very large. A physics student practices the experimental methods used to learn about this world and explores the mathematical techniques and theories developed to explain these physical phenomena. A Physics major or Astrophysics major serves as preparation for further work in physics, astrophysics, applied physics, other sciences, engineering, medical research, science teaching and writing, and other careers involving critical thinking, problem-solving, and insight into the fundamental principles of nature.

### ASTRONOMY AND ASTROPHYSICS MAJORS

The Department of Physics and Astronomy offers three distinct majors, in Physics, Astrophysics, and Astronomy. [More information about the Astrophysics and Astronomy majors can be found on the Astronomy site.](#)

### PHYSICS MAJOR

#### Introductory Courses

Students considering a major in physics should take both physics and mathematics as first-year students. Students typically begin with Physics 141 and Mathematics 150 or 151 (multivariable calculus); students who wish to begin with Physics 131 should consult with the department.

Physics 131 Introduction to Mechanics. This is designed as a first course in physics. It is suitable for students who either have not had physics before or have had some physics but are not comfortable solving "word problems" that require calculus.

Physics 141 Mechanics and Waves. Students in this course should have solid backgrounds in science and calculus, either from high school or college, including at least a year of high school physics.

The Department of Mathematics will place students in the appropriate introductory calculus course. The physics major sequence courses all make use of calculus at increasingly sophisticated levels. Therefore, students considering a Physics major should continue their mathematical preparation without interruption through the introductory calculus sequence (Mathematics 130, 140, and 150 or 151). Students are encouraged to take Physics 210 as early as possible.

### ADVANCED PLACEMENT

Students with unusually strong backgrounds in calculus and physics may place out of Physics 141 and either: 1) begin with the special seminar course Physics 151 in the fall (typically followed by Physics 210 in the spring), or 2) begin with Physics 142 in the spring (possibly along with Physics 210). Students may take either 151 or 142 but not both. On rare occasions a student with an exceptional background will be offered the option of enrolling in Physics 201.

Placement is based on AP scores, consultation with the department, and results of a placement exam administered during First Days. The exam can also be taken later in the year by arrangement with the department chair. The exam covers classical mechanics, basic wave phenomena, and includes some use of calculus techniques.

## REQUIREMENTS FOR THE MAJOR

A total of ten courses, nine in physics and one in mathematics, are required to complete the Physics major.

### Required Physics Sequence Courses (7)

Physics 141 Mechanics and Waves

Physics 142 Foundations of Modern Physics

or Physics 151 Seminar in Modern Physics

Physics 201 Electricity and Magnetism

Physics 202 Waves and Optics

Physics 210 Mathematical Methods for Scientists

Physics 301 Quantum Physics

Physics 302 Statistical Mechanics and Thermodynamics

### Required Mathematics Course (1)

Mathematics 150 or 151 Multivariable Calculus

Students entering with Advanced Placement in mathematics may obtain credit toward the major for the equivalent Mathematics 150 or 151 taken elsewhere.

### Elective Courses (2)

At least two more physics courses above the 100 level (or other approved courses as noted below) must be taken, bringing the total number of courses for the major to ten.

Students who place out of Physics 141 must substitute one additional elective course, for a total of ten courses.

Students who place out of both Physics 141 and 142 and begin their studies in Physics 201 must substitute one additional elective course, for a total of nine courses.

### Options

- Mathematics 209 or 309 may substitute for Physics 210.
- Astronomy 111 may count in place of Physics 141 if a student places out of 141 (see "advanced placement" above).
- An additional Astronomy or Astrophysics course above the introductory level that is acceptable for the astrophysics major may be counted.
- Two approved Division III courses may be substituted for one Physics course. Approval is on an individual basis at the discretion of the department chair.
- Honors work is in addition to completion of the basic major so Physics 493 and 494 do not count towards the ten courses in the major.

### PREPARATION FOR ADVANCED STUDY

Students who wish to do graduate work in physics, astrophysics, or engineering should elect courses in both physics and mathematics beyond the minimum major requirements. The first-year graduate school curriculum in physics usually includes courses in quantum mechanics, electromagnetic theory, and classical mechanics that presuppose intermediate level study of these subjects as an undergraduate. Therefore, students planning graduate work in physics should elect all of the following courses:

Physics 402T Applications of Quantum Mechanics

Physics 405T Electromagnetic Theory

Physics 411T Classical Mechanics

### ADVISING

Both majors and non-majors are encouraged to consult with the department chair or course instructors about course selections or other matters.

### THE DEGREE WITH HONORS IN PHYSICS

The degree with honors in Physics will be awarded on the basis of a senior thesis presenting the results of a substantial experimental or

theoretical investigation carried out under the direction of a faculty member in the department. There is no rigid grade point average required for admission to the program or for the awarding of the degree with honors, but it is normally expected that honors students will maintain at least a B average in physics and mathematics. Students will normally apply for admission to the program early in the spring of their junior year and during senior year these students will normally elect Physics 493, W31, and 494 in addition to the usual requirements for the major. At the end of winter study, the department will decide whether the student will be admitted to honors candidacy. Both a written thesis and a colloquium presentation of the results are required. The degree with honors will be awarded to those who meet these requirements with distinction. The degree with highest honors will be awarded to those who fulfill them with unusually high distinction.

Honors candidates will also be required to attend departmental colloquium talks.

## STUDY ABROAD

The physics community is international in scope and a career in physics (or a related field) can provide many opportunities for travel and contact with individuals from outside the United States. The physics major at Williams is a carefully structured four-year program designed to prepare students who are so inclined for graduate study at leading research institutions. While it is possible to complete the major requirements in three years, such a major will not usually not lead to further study in the field. With careful early planning on the part of a student, and close consultation with the department chair, it is possible to complete a strong major and still study abroad provided the foreign institution can provide courses which reasonably substitute or supplement those in the Williams major program. Students MUST contact departments/programs BEFORE assuming study away credit will be granted toward the major or concentration.

Here are answers to frequently asked questions related to study abroad:

**Can your department or program typically pre-approve courses for major/concentration credit?**

Yes, in many cases, though students should be sure to contact the department.

**What criteria will typically be used/required to determine whether a student may receive major/concentration credit for a course taken while on study away?**

Course title and description.

**Does your department/program place restrictions on the number of major/concentration credits that a student might earn through study away?**

No.

**Does your department/program place restrictions on the types of courses that can be awarded credit towards your major?**

No.

**Are there specific major requirements that cannot be fulfilled while on study away?**

No.

**Are there specific major requirements in your department/program that students should be particularly aware of when weighing study away options? (Some examples might include a required course that is always taught in one semester, laboratory requirements.)**

Yes. The laboratory component of Physics 301 serves as our "advanced lab course." Students often cannot get equivalent experience abroad and must take this when they return senior year (non-credit). Unless there has been a recent change, our own Oxford Program is one place students cannot get lab experience.

## OPTIONS FOR NON-MAJORS

Many students want to take a self-contained and rigorous full-year survey of physics. For such students, the most appropriate sequence will be either Physics 131 or Physics 141 followed by Physics 132, depending on the student's background in science and mathematics (see Introductory Courses above). Either of these sequences satisfies the physics requirement for medical school.

The department also offers one-semester courses designed for non-majors, including Physics 107, Physics 108, and Physics 109.

## PHYS 108 (S) Energy Science and Technology (QFR)

**Cross-listings:** ENVI 108

**Primary Cross-listing**

Energy use has skyrocketed in the United States and elsewhere in the world, causing significant economic and political shifts, as well as concerns for the environment. This course will address the physics and technology of energy generation, consumption, and conservation. It will cover a wide range

of energy sources, including fossil fuels, hydropower, solar energy, wind energy, and nuclear energy. We will discuss energy use in transportation, manufacturing, building heating and lighting, and energy storage. Students will learn to compare the efficiencies and environmental impacts of various energy sources and uses.

**Class Format:** Two meetings per week. Some weeks that means two lectures. Other weeks, that means one lecture plus one lab, with the class divided between two lab sections.

**Requirements/Evaluation:** weekly assignments, two hour tests, and a final project culminating in an oral presentation to the class and a 10-page paper; all of these will be substantially quantitative

**Prerequisites:** high school physics, high school chemistry, and mathematics at the level of MATH 130

**Enrollment Limit:** 10 per lab

**Enrollment Preferences:** non-physics majors

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

ENVI 108(D3) PHYS 108(D3)

**Quantitative/Formal Reasoning Notes:** problems sets, exams, and projects will all have a quantitative aspects.

**Attributes:** ENVI Natural World Electives

Spring 2025

LEC Section: 01 M 1:10 pm - 2:25 pm Protik K. Majumder

LAB Section: 02 R 1:10 pm - 2:25 pm Protik K. Majumder

LAB Section: 03 R 2:35 pm - 3:50 pm Protik K. Majumder

### **PHYS 109 (S) Sound, Light, and Perception (QFR)**

Light and sound allow us to perceive the world around us, from appreciating music and art to learning the details of atomic structure. Because of their importance in human experience, light and sound have long been the subject of scientific inquiry. How are sound and light related? How do physiology and neural processing allow us to hear and see the world around us? What are the origins of color and musical pitch? This course introduces the science and technology of light and sound to students not majoring in physics. We will start with the origins of sound and light as wave phenomena, and go on to topics including color, the optics of vision, the meaning of musical pitch and tone, and the physical basis of hearing. We will also discuss some recent technological applications of light, such as lasers and optical communications. The class will meet for two 75-minute periods each week for a variable mixture of lecture, discussion, and hands-on, interactive experiments.

**Class Format:** The two weekly class sections will be located in a space suitable for both lecture and hands-on laboratory-style work

**Requirements/Evaluation:** class participation, problem sets, in-class midterm, oral presentations, and a final exam, all with a quantitative component

**Prerequisites:** none

**Enrollment Limit:** 20

**Enrollment Preferences:** non-science majors

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This class will have frequent problem sets requiring substantial quantitative reasoning

Not offered current academic year

### **PHYS 131 (F) Introduction to Mechanics (QFR)**

We focus first on the Newtonian mechanics of point particles: the relationship between velocity, acceleration, and position; the puzzle of circular motion; forces, Newton's laws, and gravitation; energy and momentum; and the physics of vibrations. Then we turn to the basic properties of waves, such as interference and refraction, as exemplified by sound and light waves. We also study the optics of lenses, mirrors and the human eye. This

course is not intended for students who have successfully completed an AP physics course in high school.

**Requirements/Evaluation:** exams, labs, and weekly problem sets, all of which have a substantial quantitative component

**Prerequisites:** MATH 130; students who scored 4 or 5 on an AP physics exam, or 6 or 7 on the IB Physics HL exam may not take this course and are encouraged to take PHYS 141 instead

**Enrollment Limit:** 24 per lab

**Enrollment Preferences:** seniority

**Expected Class Size:** 60

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** PHYS 131 can lead to either PHYS 132 (for students wanting a one-year survey of physics) or PHYS 142 (for students considering a Physics or Astrophysics major)

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This class will have weekly problem sets requiring substantial quantitative reasoning

Fall 2024

LEC Section: 01 MWF 11:00 am - 11:50 am Graham K. Giovanetti

LAB Section: 02 M 1:00 pm - 4:00 pm Graham K. Giovanetti

LAB Section: 03 T 1:00 pm - 4:00 pm Graham K. Giovanetti

### **PHYS 132 (S) Electromagnetism and the Physics of Matter (QFR)**

This course is intended as the second half of a one-year survey of physics with some emphasis on applications to medicine. In the first part of the semester we will focus on electromagnetic phenomena. We will introduce the concept of electric and magnetic fields and study in detail the way in which electrical circuits and circuit elements work. The deep connection between electric and magnetic phenomena is highlighted with a discussion of Faraday's Law of Induction. Following our introduction to electromagnetism we will discuss some of the most central topics in twentieth-century physics, including Einstein's theory of special relativity and some aspects of quantum theory. We will end with a treatment of nuclear physics, radioactivity, and uses of radiation.

**Class Format:** lecture three hours per week, laboratory three hours approximately every other week, and conference section 1 hour approximately every other week

**Requirements/Evaluation:** weekly problem sets, labs, quizzes and exams

**Prerequisites:** PHYS 131 or 141 or permission of instructor, and MATH 130 (formerly 103)

**Enrollment Limit:** 22 per lab

**Enrollment Preferences:** sophomores

**Expected Class Size:** 60

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** Significant homework, exams, quizzes requiring mathematical and physical reasoning.

Spring 2025

LEC Section: 01 MWF 11:00 am - 11:50 am Catherine Kealhofer

LAB Section: 02 M 1:00 pm - 4:00 pm Catherine Kealhofer

LAB Section: 03 T 1:00 pm - 4:00 pm Catherine Kealhofer

### **PHYS 141 (F) Mechanics and Waves (QFR)**

This is the typical first course for a prospective physics major. It covers most of the same topics as PHYS 131, but with a higher level of mathematical sophistication. It is intended for students with solid backgrounds in the sciences, either from high school or college, who are comfortable with basic calculus.

**Class Format:** lecture, three hours per week; laboratory, three hours approximately every other week; conference section, 1.5 hours approximately

every other week

**Requirements/Evaluation:** weekly problem sets, labs, two 1-hour exams, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** High school physics (strongly recommended) and MATH 130 or equivalent placement, or permission of the instructor. High school physics at the AP, IB, or equivalent level is neither required nor expected.

**Enrollment Limit:** 24 per lab

**Enrollment Preferences:** first-year students and science majors

**Expected Class Size:** 40

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** PHYS 141 can lead to either PHYS 132 (for students wanting a one-year survey of physics) or PHYS 142 (for students considering a Physics or Astrophysics major)

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This course consists of lectures, problem-solving conferences, lab exercises, problem sets and exams, all of which have a substantial quantitative component.

Fall 2024

LEC Section: 01 MWF 11:00 am - 11:50 am Betül Pamuk

LAB Section: 02 M 1:00 pm - 4:00 pm Betül Pamuk

LAB Section: 03 T 1:00 pm - 4:00 pm Betül Pamuk

### **PHYS 142 (S) Foundations of Modern Physics (QFR)**

Newtonian Mechanics, spectacular as it is in describing planetary motion and a wide range of other phenomena, only hints at the richness of behaviors seen in the universe. Special relativity, which extends physics into the realm of high speeds and high energies, requires we rethink our basic notions of space and time. Quantum mechanics successfully describes atoms, molecules, and solids while at the same time calling into question our expectation of what can be predicted by a physical theory. Statistical physics reveals new behaviors that emerge when many particles are present in a system. This course will survey ideas from each of these three arenas, and can serve either as a terminal course for those seeking to complete a year of physics or as the basis for future advanced study of these topics.

**Class Format:** lecture, three hours weekly; laboratory, 2-3 hours most weeks, alternating between 'hands-on' sessions and problem-solving/discussion sessions

**Requirements/Evaluation:** weekly homework, labs, two hour tests, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 141 and MATH 130, or equivalent; PHYS 131 may substitute for PHYS 141 with the permission of instructor; students may not take both PHYS 142 and PHYS 151

**Enrollment Limit:** 14/L

**Enrollment Preferences:** first-year students

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** Heavily problem-solving focused, involving algebraic manipulations, single-variable calculus, generating and reading graphs, etc.

Spring 2025

LEC Section: 01 MWF 11:00 am - 11:50 am Graham K. Giovanetti

LAB Section: 02 M 1:00 pm - 4:00 pm Graham K. Giovanetti

LAB Section: 03 T 1:00 pm - 4:00 pm Graham K. Giovanetti

### **PHYS 151 (F) Seminar in Modern Physics (QFR)**

Newtonian Mechanics, spectacular as it is in describing planetary motion and a wide range of other phenomena, only hints at the richness of behaviors

seen in the universe. Special relativity has extended physics into the realm of high speeds and high energies and requires us to rethink our basic notions of space and time. Quantum mechanics successfully describes atoms, molecules, and solids while at the same time calling into question our notions of what can be predicted by a physical theory. Statistical physics reveals new behaviors that emerge when many particles are present in a system. This course covers the same core material as PHYS 142 but in a small seminar format for students with strong prior preparation in physics.

**Class Format:** lecture/discussions plus one 3-hour lab per week

**Requirements/Evaluation:** class participation, weekly lab assignments, weekly problem sets, exams

**Prerequisites:** placement by the department (see "advanced placement" section in the description about the department). Students may take either PHYS 142 or PHYS 151 but not both

**Enrollment Limit:** 18

**Enrollment Preferences:** first-years

**Expected Class Size:** 16

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** this is a small seminar designed for first-year students who have placed out of PHYS 141

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** all assignments in the course have a substantial quantitative component

Fall 2024

LEC Section: 01 MWF 11:00 am - 12:15 pm Catherine Kealhofer

LAB Section: 02 T 1:00 pm - 4:00 pm Catherine Kealhofer

### **PHYS 201 (F) Electricity and Magnetism (QFR)**

The classical theory of electricity and magnetism is very rich yet it can be written in a remarkably succinct form using Maxwell's equations. This course is an introduction to electricity and magnetism and their mathematical description, connecting electric and magnetic phenomena via the special theory of relativity. Topics include electrostatics, magnetic fields, electromagnetic induction, DC and AC circuits, and the electromagnetic properties of matter. The laboratory component of the course is an introduction to electronics where students will develop skills in building and debugging electrical circuits.

**Class Format:** lecture, three hours per week; laboratory, three hours per week

**Requirements/Evaluation:** problem sets, labs/conference section assignments, two midterms, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 142 OR 151; MATH 150 or 151; with a preference for MATH 151

**Enrollment Limit:** 10 per lab

**Enrollment Preferences:** prospective physics majors, then by seniority

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This course involves significant problem-solving and mathematical analysis of phenomena using calculus, numerical methods, and other quantitative tools.

Fall 2024

LEC Section: 01 MWF 10:00 am - 10:50 am David R. Tucker-Smith

LAB Section: 02 W 1:00 pm - 4:00 pm David R. Tucker-Smith

LAB Section: 03 R 1:00 pm - 4:00 pm David R. Tucker-Smith

### **PHYS 202 (S) Vibrations, Waves and Optics (QFR)**

Waves and oscillations characterize many different physical systems, including vibrating strings and springs, waves at the beach, or those that we hear as sound or see as light. Quantum mechanics describes particles with wave functions, and gravitational waves distort the very fabric of the

universe. Despite these diverse settings, waves exhibit several common characteristics, so understanding of a few simple systems can provide insight into a wide array of phenomena. In this course we begin with the study of oscillations of simple systems with only a few degrees of freedom. We then move on to study transverse and longitudinal waves in continuous media in order to gain a general description of wave behavior. We conclude with a focus on electromagnetic waves and in particular on optical examples of wave phenomena such as interference, diffraction, and lasers. Throughout the course we will introduce and develop mathematical tools which will continue to see use in higher-level physics.

**Class Format:** lecture, three hours per week; laboratory, three hours per week

**Requirements/Evaluation:** problem sets, labs, midterm examinations, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 201; co-requisite: PHYS/MATH 210 or MATH 309 or permission of instructor

**Enrollment Limit:** 30

**Enrollment Preferences:** sophomores

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** Weekly problem sets and laboratories which develop and use quantitative skills.

Spring 2025

LEC Section: 01 MWF 10:00 am - 10:50 am Katharine E. Jensen

LAB Section: 02 W 1:00 pm - 4:00 pm Frederick W. Strauch

LAB Section: 03 R 1:00 pm - 4:00 pm Frederick W. Strauch

### **PHYS 210 (S) Mathematical Methods for Scientists (QFR)**

**Cross-listings:** MATH 210

**Primary Cross-listing**

This course covers a variety of mathematical methods used in the sciences, focusing particularly on the solution of ordinary and partial differential equations. In addition to calling attention to certain special equations that arise frequently in the study of waves and diffusion, we develop general techniques such as looking for series solutions and, in the case of nonlinear equations, using phase portraits and linearizing around fixed points. We study some simple numerical techniques for solving differential equations. An optional session in Mathematica will be offered for students who are not already familiar with this computational tool.

**Class Format:** three hours per week

**Requirements/Evaluation:** several exams and weekly problem sets, all of which have a substantial quantitative component

**Prerequisites:** MATH 150 or 151 and familiarity with Newtonian mechanics at the level of PHYS 131

**Enrollment Limit:** 50

**Enrollment Preferences:** sophomores and juniors

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

PHYS 210(D3) MATH 210(D3)

**Quantitative/Formal Reasoning Notes:** This course will have weekly problem sets using advanced calculus methods

Spring 2025

LEC Section: 01 TR 9:55 am - 11:10 am Frederick W. Strauch

### **PHYS 234 (S) Introduction to Materials Science (QFR)**

**Cross-listings:** GEOS 234



### Primary Cross-listing

Materials Science is the study of how the microscopic structure of materials--whether steel, carbon fiber, glass, wood, plastic, or mayonnaise--determines their macroscopic mechanical, thermal, electric, and other properties. Topics of this course include classifying materials; material structure; thermodynamics and phase transformations; material properties and testing; how solids bend, flow, and ultimately break; and how to choose the right material for design applications. Materials Science is a highly interdisciplinary field and as a result the course prerequisites are broad but also flexible. Interested students who are unsure about their preparation are strongly encouraged to contact the instructor.

**Class Format:** lecture (3 hours per week) plus up to two small-group laboratory sessions throughout the semester (to be scheduled with instructor)

**Requirements/Evaluation:** weekly problem sets, class participation, midterm and final exams, and a 3-5 page paper and associated presentation, all of which have a substantial quantitative component

**Prerequisites:** high school physics and chemistry, preferably at the AP level, and MATH 140 or AP Calculus (BC), and one 100-level PHYS, CHEM, or GEOS course; or permission of instructor

**Enrollment Limit:** 24

**Enrollment Preferences:** based on students' scientific background and seniority

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** This course does not count toward the Geosciences major.

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

PHYS 234(D3) GEOS 234(D3)

**Quantitative/Formal Reasoning Notes:** Weekly problem sets and exams all have a substantial quantitative component.

**Attributes:** MTSC Courses

Spring 2025

LEC Section: 01 MR 2:35 pm - 3:50 pm Katharine E. Jensen

### PHYS 301 (F) Quantum Physics (QFR)

This course serves as a one-semester introduction to the formalism, and phenomenology of quantum mechanics, beginning with a discussion of the Schrodinger wave equation, the concept of matter waves, and wave-packets. With this introduction as background, we will continue our discussion with a variety of one-dimensional problems such as the particle-in-a-box and the harmonic oscillator. We then extend this work to systems in two and three dimensions, including a detailed discussion of the structure of the hydrogen atom. Along the way we will develop connections between mathematical formalism and physical predictions of the theory. Finally, we conclude the course with a discussion of angular momentum and spins, with applications to atomic physics, entanglement, and quantum information.

**Class Format:** lecture, three hours per week; laboratory, three hours per week

**Requirements/Evaluation:** weekly problem sets, laboratory reports / write-ups, a midterm exam, and final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 202 and PHYS/MATH 210 or MATH 309

**Enrollment Limit:** 8 per lab

**Enrollment Preferences:** physics majors

**Expected Class Size:** 24

**Grading:** yes pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** Phys 301 relies heavily upon mathematics and quantitative reasoning in all elements, including problem sets, examinations, and laboratories.

Fall 2024

LEC Section: 01 MWF 9:00 am - 9:50 am Charlie Doret

LAB Section: 02 M 1:00 pm - 4:00 pm Charlie Doret, Frederick W. Strauch  
LAB Section: 03 W 1:00 pm - 4:00 pm Charlie Doret, Frederick W. Strauch  
LAB Section: 04 R 1:00 pm - 4:00 pm Charlie Doret, Frederick W. Strauch  
LAB Section: 05 T 1:00 pm - 4:00 pm Charlie Doret, Frederick W. Strauch

### **PHYS 302 (S) Statistical Mechanics & Thermodynamics (QFR)**

Macroscopic objects are made up of huge numbers of fundamental particles interacting in simple ways--obeying the Schrödinger equation, Newton's and Coulomb's Laws--and these objects can be described by macroscopic properties like temperature, pressure, magnetization, heat capacity, conductivity, etc. In this course we will develop the tools of statistical physics, which will allow us to predict the cooperative phenomena that emerge in large ensembles of interacting particles. We will apply those tools to a wide variety of physical questions, including the behavior of gases, polymers, heat engines, biological and astrophysical systems, magnets, and electrons in solids.

**Class Format:** lecture/discussion three hours per week and weekly laboratory work

**Requirements/Evaluation:** weekly problem sets and labs, plus exams, all of which have a substantial quantitative component

**Prerequisites:** required: PHYS 201, PHYS/MATH 210 or MATH 309; recommended: PHYS 202, PHYS 301

**Enrollment Limit:** 14 per lab

**Enrollment Preferences:** physics majors

**Expected Class Size:** 25

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** weekly problem sets, exams, and labs, all of which have a substantial quantitative component

Spring 2025

LEC Section: 01 MWF 9:00 am - 9:50 am Daniel P. Aalberts

LAB Section: 02 W 1:10 pm - 3:50 pm Daniel P. Aalberts

LAB Section: 03 R 1:10 pm - 3:50 pm Daniel P. Aalberts

### **PHYS 312 (F) Philosophical Implications of Modern Physics (QFR)**

**Cross-listings:** PHIL 312 / STS 312

**Primary Cross-listing**

Some of the discoveries made by physicists over the last century seem to show that our common sense views are deeply at odds with our most sophisticated and best confirmed scientific theories. The course will present the essential ideas of relativity theory and quantum theory and explore their implications for philosophy. We will ask, for example, what these theories tell us about the nature of space, time, probability and causality.

**Requirements/Evaluation:** attendance, participation, problem sets, exams, six 1- to 2-page papers and a 12- to 15-page term paper

**Prerequisites:** MATH 140, high-school physics, and either a 200-level course in PHIL or a 100-level course in PHYS

**Enrollment Limit:** 20

**Enrollment Preferences:** Philosophy majors and Physics majors

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

PHYS 312(D3) PHIL 312(D2) STS 312(D2)

**Attributes:** PHIL Contemp Metaphysics + Epistemology Courses

**Not offered current academic year**

### **PHYS 314 (S) Controlling Quanta (QFR)**

This course will explore modern developments in the control of individual quantum systems. Topics covered will include basic physical theories of atoms coupled to photons, underlying mathematical tools (including Lie algebras and groups), and computational methods to simulate and analyze quantum systems. Applications to quantum computing, teleportation, and experimental metaphysics (Bell's inequality) will also be discussed.

**Requirements/Evaluation:** tutorial preparation and participation, weekly problem sets/papers, and a final project

**Prerequisites:** PHYS/MATH 210 or MATH 209 or MATH 250

**Enrollment Limit:** 10

**Enrollment Preferences:** sophomores and junior Physics majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This course involves weekly problems sets involving linear algebra, calculus, and other mathematical methods.

Not offered current academic year

### **PHYS 315 (F) Computational Biology (QFR)**

**Cross-listings:** CSCI 315

Primary Cross-listing

This course will provide an overview of Computational Biology, the application of computational, mathematical, statistical, and physical problem-solving techniques to interpret the rapidly expanding amount of biological data. Topics covered will include database searching, DNA sequence alignment, clustering, RNA structure prediction, protein structural alignment, methods of analyzing gene expression, networks, and genome assembly using techniques such as string matching, dynamic programming, hidden Markov models, and statistics.

**Requirements/Evaluation:** weekly Python programming assignments, code reviews, problem sets, plus a few quizzes and a final project

**Prerequisites:** programming experience (e.g., CSCI 136) and mathematics (PHYS/MATH 210 or MATH 150) and physical science (PHYS 142/151, or CHEM 101/15X), or permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** if over-enrolled, a questionnaire will be circulated

**Expected Class Size:** 8

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

CSCI 315(D3) PHYS 315(D3)

**Quantitative/Formal Reasoning Notes:** problem sets and programming assignments

**Attributes:** BIGP Courses

Fall 2024

LEC Section: 01 MR 2:35 pm - 3:50 pm Daniel P. Aalberts

### **PHYS 319 (S) Integrative Bioinformatics, Genomics, and Proteomics Lab (QFR)**

**Cross-listings:** BIOL 319 / CHEM 319 / CSCI 319 / MATH 319

Secondary Cross-listing

What can computational biology teach us about cancer? In this lab-intensive experience for the Genomics, Proteomics, and Bioinformatics program, computational analysis and wet-lab investigations will inform each other, as students majoring in biology, chemistry, computer science, mathematics/statistics, and physics contribute their own expertise to explore how ever-growing gene and protein data-sets can provide key insights into human disease. In this course, we will take advantage of one well-studied system, the highly conserved Ras-related family of proteins, which play a central role in numerous fundamental processes within the cell. The course will integrate bioinformatics and molecular biology, using database searching, alignments and pattern matching, and phylogenetics to reconstruct the evolution of gene families by focusing on the gene duplication

events and gene rearrangements that have occurred over the course of eukaryotic speciation. By utilizing high through-put approaches to investigate genes involved in the inflammatory and MAPK signal transduction pathways in human colon cancer cell lines, students will uncover regulatory mechanisms that are aberrantly altered by siRNA knockdown of putative regulatory components. This functional genomic strategy will be coupled with independent projects using phosphorylation-state specific antisera to test our hypotheses. Proteomic analysis will introduce the students to de novo structural prediction and threading algorithms, as well as data-mining approaches and Bayesian modeling of protein network dynamics in single cells. Flow cytometry and mass spectrometry may also be used to study networks of interacting proteins in colon tumor cells.

**Class Format:** The lab for this course will meet for two afternoons per week. Some lab sessions will be shorter than 3 hours.

**Requirements/Evaluation:** lab participation, several short homework assignments, one lab report, a programming project, and a grant proposal

**Prerequisites:** BIOL 202; students who have not taken BIOL 202 but have taken BIOL 101 and a CSCI course, or CSCI/PHYS 315, may enroll with permission of instructor. No prior computer programming experience is required.

**Enrollment Limit:** 12

**Enrollment Preferences:** seniors, then juniors, then sophomores

**Expected Class Size:** 12

**Grading:** yes pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

BIOL 319(D3) CHEM 319(D3) CSCI 319(D3) PHYS 319(D3) MATH 319(D3)

**Quantitative/Formal Reasoning Notes:** Through lab work, homework sets and a major project, students will learn or further develop their skills in programming in Python, and about the basis of Bayesian approaches to phylogenetic tree estimation.

**Attributes:** BIGP Courses BIMO Interdepartmental Electives

Not offered current academic year

### **PHYS 321 (S) Introduction to Particle Physics (QFR)**

The Standard Model of particle physics incorporates special relativity, quantum mechanics, and almost all that we know about elementary particles and their interactions. This course introduces some of the main ideas and phenomena associated with the Standard Model. After a review of relativistic kinematics, we will learn about symmetries in particle physics, relativistic wave equations, elements of quantum field theory, Feynman diagrams, and selected applications of quantum electrodynamics, the weak interactions, and quantum chromodynamics. We will conclude with a discussion of spontaneous symmetry breaking and the Higgs mechanism.

**Requirements/Evaluation:** weekly problem sets, a midterm exam, and a final exam

**Prerequisites:** PHYS 301

**Enrollment Limit:** 20

**Enrollment Preferences:** By seniority

**Expected Class Size:** 10

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** Exams and problem sets all have a significant quantitative component.

Spring 2025

LEC Section: 01 TR 8:30 am - 9:45 am David R. Tucker-Smith

### **PHYS 402 (S) Applications of Quantum Mechanics (QFR)**

This course will explore a number of important topics in the application of quantum mechanics to physical systems, including perturbation theory, the variational principle and the semiclassical interaction of atoms and radiation. The course will finish up with three weeks on quantum optics including an experimental project on non-classical interference phenomena. Applications and examples will be taken mostly from atomic physics with some discussion of solid state systems.

**Requirements/Evaluation:** weekly problem sets, tutorial participation, presentations, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 301

**Enrollment Limit:** 10 per sec

**Enrollment Preferences:** Physics and Astrophysics Majors

**Expected Class Size:** 16

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This course has weekly problem sets, all of which have a substantial quantitative component.

Spring 2025

TUT Section: T1 F 1:10 pm - 2:25 pm Betül Pamuk

### **PHYS 405 (F) Electromagnetic Theory (QFR)**

This course builds on the material of Physics 201, and explores the application of Maxwell's Equations to understand a range of topics including electric fields and matter, magnetic materials, light, and radiation. As we explore diverse phenomena, we will learn useful approximation techniques and beautiful mathematical tools. In addition to weekly tutorial meetings, the class will meet once a week as a whole to introduce new material.

**Class Format:** Class will meet once as a whole to introduce new material and for informal discussion.

**Requirements/Evaluation:** weekly problem sets, tutorial participation, presentations, and a final exam or final project, all of which have a substantial quantitative component

**Prerequisites:** PHYS 202 and PHYS/MATH 210 or MATH 209 or MATH 309

**Enrollment Limit:** 30

**Enrollment Preferences:** Preference will be given to physics and astrophysics majors.

**Expected Class Size:** 18

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** Physics courses are all heavily dependent on QFR skills. Phys 405 will feature extensive use of vector calculus and differential equations while also asking students to develop facility with approximation techniques in solving complex problems throughout the semester.

Not offered current academic year

### **PHYS 411 (F) Classical Mechanics (QFR)**

This course will explore advanced topics in classical mechanics. Central ideas include the calculus of variations, the Lagrangian and Hamiltonian formulations of mechanics, phase space, central-force motion, non-inertial reference frames (including implications for physics on a rotating Earth), rigid-body rotations, and non-linear dynamics and chaos, with additional topics from continuum and fluid mechanics as time permits. Numerical and perturbative techniques will be developed and used extensively. We will also examine the ways in which classical mechanics informs other fields of physics. In addition to weekly tutorial meetings the class will meet weekly as a whole to introduce and discuss new material.

**Requirements/Evaluation:** weekly problem sets, tutorial participation, presentations, a final project, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 202 and PHYS/MATH 210 or MATH 309

**Enrollment Limit:** 30

**Enrollment Preferences:** majors

**Expected Class Size:** 24

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** weekly problem sets requiring substantial quantitative reasoning using analytical and numerical methods.

Fall 2024

**PHYS 418 (S) Gravity (QFR)**

This course is an introduction Einstein's theory of general relativity. We begin with a review of special relativity, emphasizing geometrical aspects of Minkowski spacetime. Working from the equivalence principle, we then motivate gravity as spacetime curvature, and study in detail the Schwarzschild geometry around a spherically symmetric mass. After this application, we use tensors to develop Einstein's equation, which describes how energy density curves spacetime. With this equation in hand we study the Friedmann-Robertson-Walker geometries for an expanding universe, and finally, we linearize Einstein's equation to develop the theory of gravitational waves.

**Requirements/Evaluation:** weekly problem sets, a midterm exam, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 301 or PHYS 405 or PHYS 411, or permission of instructor

**Enrollment Limit:** none

**Enrollment Preferences:** none

**Expected Class Size:** 10

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** All problem sets and exams will have a substantial quantitative component.

Not offered current academic year

**PHYS 451 (F) Condensed Matter Physics (QFR)**

Condensed matter physics is an important area of current research and serves as the basis for modern electronic technology. We plan to explore the physics of metals, insulators, semiconductors, superconductors, and photonic crystals, with particular attention to structure, thermal properties, energy bands, and electronic properties.

**Requirements/Evaluation:** weekly readings and problem sets, and exams

**Prerequisites:** PHYS 301 (may be taken simultaneously); or permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** Physics majors

**Expected Class Size:** 6

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** serious problem sets

**Attributes:** MTSC Courses

Fall 2024

SEM Section: 01 MR 1:10 pm - 2:25 pm Daniel P. Aalberts

**PHYS 493 (F) Senior Research: Physics**

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Physics, as discussed above under the heading of *The Degree with Honors in Physics*.

**Requirements/Evaluation:** presentation and preparation of thesis

**Prerequisites:** permission of department; senior course

**Enrollment Limit:** 20

**Enrollment Preferences:** senior majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3)

Fall 2024

HON Section: 01 TBA David R. Tucker-Smith

**PHYS 494 (S) Senior Research: Physics**

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Physics, as discussed above under the heading of *The Degree with Honors in Physics*.

**Prerequisites:** permission of department; senior course

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3)

Spring 2025

HON Section: 01 TBA David R. Tucker-Smith

**PHYS 495 (F) Senior Research: Astrophysics**

**Cross-listings:** ASTR 495

**Secondary Cross-listing**

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Astronomy or Physics, as discussed under the heading of the degree with honors in Astrophysics above.

**Prerequisites:** permission of department

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3)

**This course is cross-listed and the prefixes carry the following divisional credit:**

ASTR 495(D3) PHYS 495(D3)

Fall 2024

HON Section: 01 TBA David R. Tucker-Smith

**PHYS 496 (S) Senior Research: Astrophysics**

**Cross-listings:** ASTR 496

**Secondary Cross-listing**

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Astronomy or Physics, as discussed under the heading of the degree with honors in Astrophysics above.

**Prerequisites:** permission of department

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3)

**This course is cross-listed and the prefixes carry the following divisional credit:**

ASTR 496(D3) PHYS 496(D3)

Spring 2025

HON Section: 01 TBA David R. Tucker-Smith

**PHYS 497 (F) Independent Study: Physics**

Physics independent study.

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3)

Fall 2024

IND Section: 01 TBA David R. Tucker-Smith

**PHYS 498 (S) Independent Study: Physics**

Physics independent study.

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3)

Spring 2025

IND Section: 01 TBA David R. Tucker-Smith

**PHYS 499 (F)(S) Physics and Astronomy Colloquium**

**Cross-listings:** ASTR 499

**Primary Cross-listing**

Physicists and Astronomers from around the country come to explain their research. Students of Physics and Astronomy at any level are welcome. Registration is not necessary to attend. A non-credit course.

**Class Format:** colloquium

**Requirements/Evaluation:** not a for-credit course

**Prerequisites:** none

**Enrollment Limit:** none

**Enrollment Preferences:** none

**Grading:** non-graded

**Unit Notes:** registration not necessary to attend

**Distributions:** No divisional credit

**This course is cross-listed and the prefixes carry the following divisional credit:**

PHYS 499No divisional credit ASTR 499No divisional credit

Fall 2024

LEC Section: 01 F 2:35 pm - 3:50 pm David R. Tucker-Smith

Spring 2025

LEC Section: 01 F 2:35 pm - 3:50 pm David R. Tucker-Smith

**Winter Study -----**

**PHYS 10 (W) Light and Holography**

This course will examine the art and science of holography. It will introduce modern optics at a level appropriate for a non-science major, giving the necessary theoretical background in lectures and discussion. Demonstrations will be presented and students will make several kinds of holograms in the lab. Thanks to a grant from the National Science Foundation, we have 7 well-equipped holography darkrooms available for student use. At the beginning of WSP, the class will meet for lecture and discussion three mornings a week and for lab 2 afternoons a week. The later part of the month will be mainly open laboratory time during which students, working in small groups, will conduct an independent project in holography approved by the instructor. Attendance at lectures and laboratory is required. Lectures will be in the morning, labs will be in the afternoon. A detailed schedule will be circulated to students who sign up for this course. Students who cannot attend the required sessions will be advised to select a different course as it is



not possible to achieve a passing grade without being able to attend the classes and laboratories.

**Class Format:** The course has lecture and lab components, as detailed in the course description.

**Requirements/Evaluation:** attendance at all classes and labs, completion of 4 laboratory exercises, and a holography laboratory project (approved by the instructor); final poster presentation

**Prerequisites:** none

**Enrollment Limit:** 30

**Enrollment Preferences:** preference to students with no physics above Physics 109; then seniors, juniors, sophomores and first-years

**Expected Class Size:** 20

**Grading:** pass/fail only

**Unit Notes:** The course will be taught by Physics Department members Kevin Forkey (lectures) and Brough Morris (labs).

**Materials/Lab Fee:** \$50

Winter 2025

LEC Section: 01 MWF 10:00 am - 12:00 pm Kevin R. Forkey

### **PHYS 12 (W) Drawing as a Learnable Skill**

Representational drawing is not merely a gift of birth, but a learnable skill. If you wanted to draw, but have never had the time to learn; or you enjoy drawing and wish to deepen your understanding and abilities, then this course is for you. This intensive course utilizes traditional drawing exercises to teach representational drawing. By using simple techniques and extensive exercises you will develop your ability to accurately see and realistically represent the physical world. You will learn to draw a convincing portrait, interior, and still life. This course is designed to develop your powers of observation and teach creative problem solving abilities. Students need no previous artistic experience, just the willingness and desire to learn. Students will be expected to attend and participate in all sessions. They will also be required to keep a sketchbook recording their progress and complete a final project. Evaluations will be based on participation, effort, and development.

**Requirements/Evaluation:** Other: Evaluations will be based on class attendance, participation, effort, and development.

**Prerequisites:** No prerequisites.

**Enrollment Limit:** 18

**Enrollment Preferences:** If overenrolled, selection will be based on seniority.

**Expected Class Size:** NA

**Grading:** pass/fail only

**Unit Notes:** Stella Ehrich is a professional painter whose work includes portraits, landscapes and still life subjects. She studied for seven years at Studio Simi in Florence, she holds an MFA from Bennington College and a BFA from the Memphis Academy of Art.

**Materials/Lab Fee:** \$35

**Attributes:** EXPE Experiential Education Courses SLFX Winter Study Self-Expression

Winter 2025

STU Section: 01 TR 10:00 am - 1:00 pm Stella Ehrich

### **PHYS 22 (W) Research Participation**

Several members of the department will have student projects available dealing with their own research or that of current senior thesis students. Approximately 35 hours per week of study and actual research participation will be expected from each student.

**Class Format:** to be arranged with instructor

**Requirements/Evaluation:** students will be required to keep a notebook and write a 5-page paper summarizing their work

**Prerequisites:** permission of instructor

**Enrollment Limit:** 1-2

**Enrollment Preferences:** permission of instructor

**Grading:** pass/fail only

Winter 2025

RSC Section: 01 TBA David R. Tucker-Smith

**PHYS 31 (W) Senior Research: Physics**

To be taken by students registered for Physics 493, 494.

**Class Format:** thesis

**Grading:** pass/fail only

Winter 2025

HON Section: 01 TBA David R. Tucker-Smith

**PHYS 32 (W) Senior Research: Astrophysics**

**Cross-listings:** ASTR 32

**Secondary Cross-listing**

To be taken by students registered for Astrophysics 495, 496.

**Class Format:** independent study

**Grading:** pass/fail only

**This course is cross-listed and the prefixes carry the following divisional credit:**

ASTR 32PHYS 32

Winter 2025

HON Section: 01 TBA David R. Tucker-Smith

**PHYS 99 (W) Independent Study: Physics**

Open to upperclass students. Students interested in doing an independent project (99) during Winter Study must make prior arrangements with a faculty sponsor. The student and professor then complete the independent study proposal form available online. The deadline is typically in late September. Proposals are reviewed by the pertinent department and the Winter Study Committee. Students will be notified if their proposal is approved prior to the Winter Study registration period.

**Class Format:** independent study

**Grading:** pass/fail only

Winter 2025

IND Section: 01 TBA David R. Tucker-Smith