Requirements: Physics

Natural Sciences Division

Physics is the study of the most basic principles of nature that describe the world around us, from subatomic particles, to the motion of everyday objects to the galaxies and beyond. Courses in physics allow students to develop a sound knowledge of these principles as well as the analytical, computational and experimental techniques necessary to apply them to a broad range of theoretical and experimental problems. A physics degree is excellent preparation for graduate school in physics and engineering and for careers in the health sciences, law and teaching.

The Kenyon College faculty voted to change from Kenyon units to semester hours. This change will go into effect for all students who start at the College in the fall of 2024. Both systems will be used throughout the course catalog with the Kenyon units being listed first.

The Curriculum

The Department of Physics offers three options for students wishing to begin their exploration of physics.

1. Students interested in exploring physics as a potential major or minor should begin by taking PHYS 140 and 141 and PHYS 145 and 146 in their first year. Together with PHYS 240 and 241, these courses form a calculus-based introduction to physics particularly suitable for students who plan to take upper-level courses in physics, chemistry and/or mathematics. PHYS 140 and 145 require concurrent enrollment in or credit for "Calculus I and II," respectively, and each has a co-requisite laboratory course. PHYS 141, corequisite to PHYS 140 for first-year students, is a weekly seminar open only to first-year students enrolled in PHYS 140 or holding credit for an equivalent course. It

introduces students to laboratory work in physics in the context of one of the subdisciplines of physics pursued by faculty members in the department. Recent seminar topics have included nanoscience, cold atom physics, gravitation, astrophysics and particle physics. PHYS 131, co-requisite to PHYS 140 for upper-class students, and PHYS 146 are weekly laboratories, closely tied to lecture material; they make extensive use of computers for data acquisition and analysis.

2. First-year students who have unusually strong physics preparation from high school, may want to consider beginning their study of physics with PHYS 240 (plus PHYS 141 as their co-requisite lab course) in the first semester, followed by PHYS 145 and 146 in the second semester. Such preparation includes a high score on the Advanced Placement C-level physics examination, experience with quantitative laboratory measurement, significant use of calculus in high school physics and placement into Calculus III. Placement into PHYS 240 is determined in consultation with the instructor and chair of the department.

3. Students who desire a more qualitative approach to physics and do not intend to major in physics or pursue 3-2 engineering can choose from an array of courses designed to engage learners in the physics relevant to various interesting subfields of the discipline. Recent course offerings in this series have included PHYS 100 (QR), PHYS 101 (QR), PHYS 102 (QR), PHYS 103, PHYS 104 (QR), PHYS 105 (QR), PHYS 106, PHYS 107 (QR), PHYS 108 and PHYS 109. These courses are suitable for diversification in the sciences and are accessible to any Kenyon student regardless of class year or preparation. Those including the QR designation also satisfy the College's quantitative reasoning requirement, making regular, weekly use of numerical, statistical and/or graphical techniques to help students explore the material in quantitative ways. All contain some laboratory sessions in which students gain experience with the phenomena discussed in lectures. Usually, one or two such courses are offered each semester.

4. Upper-class students seeking a one-year survey of physics with laboratory should take PHYS 130 and 135 and the co-requisite laboratory courses, PHYS 131 and 136. Entry into PHYS 130 and 135 requires sophomore standing; no first-year students will be admitted to these courses. Co-requisite laboratory courses must be taken in the same semester as the associated survey course.

A student preparing for graduate study in physics should complete more than the minimum requirements. These students should consider taking all of the four fall lecture courses, which cover the core subjects of classical mechanics, thermodynamics and statistical mechanics, electrodynamics, and quantum mechanics, as well as at least one 0.5 unit/4 semester hour math course numbered MATH 220 or above. Coursework in chemistry may also be recommended. Specific courses that will best prepare a student for graduate studies in physics can vary depending on the physics field specialization. A student preparing for graduate studies in physics should consult with a member of the physics faculty about which courses would be most beneficial for a given specialization. A student preparing for graduate study should expect to average more than 2.0 units/16 semester hours per semester. Care should be taken to satisfy the College's graduation requirement to take 9 units/72 semester hours outside of the major department.

A student preparing for graduate or second bachelor's degree work in engineering will need to complete a year of chemistry with lab as well as one semester of differential equations.

All courses in physics numbered above 220 have as prerequisites PHYS 140 and 145 and MATH 111 and 112, unless otherwise noted. PHYS 131, 136, 141, 146, 241 and courses numbered 380–387 are laboratory courses involving substantial experimental work.

Requirements for the Major

The minimum requirements for a major in physics consist of the following:

- PHYS 140: Classical Physics

- PHYS 141: First-Year Seminar in Physics
- PHYS 145: Modern Physics
- PHYS 146: Modern Physics Lab
- PHYS 240: Fields and Spacetime
- PHYS 241: Fields and Spacetime Laboratory
- PHYS 245: Oscillations and Waves
- PHYS 270: Introduction to Computational Physics
- In extraordinary circumstances, PHYS 130, 131 and 135, 136 may be substituted for PHYS 140, 141 and 145, 146 with permission of the department chair.
- Four courses of experimental physics:
  - PHYS 380: Introduction to Electronics
  - PHYS 385: Advanced Experimental Physics 1
  - Two courses chosen from:
    - PHYS 381: Projects in Electronics 1
    - PHYS 382: Projects in Electronics 2
    - PHYS 386: Advanced Experimental Physics 2
    - PHYS 387: Advanced Experimental Physics 3
- Two courses of theoretical physics:
  - PHYS 340: Classical Mechanics
  - PHYS 345: Astrophysics and Particles
  - PHYS 350: Electricity and magnetism
  - PHYS 355: Optics
  - PHYS 360: Quantum Mechanics

    - PHYS 365: Quantum Mechanics II
    - PHYS 370:Thermodynamics and Statistical Mechanics
    - PHYS 375: Condensed Matter Physics
    - At least one of:
        - PHYS 340: Classical Mechanics
        - PHYS 350: Electricity and Magnetics
        - PHYS 360: Quantum Mechanics
- Additional .5 units/4 semester hours selected from experimental or theoretical physics courses numbered above 320.
- MATH 111, 112, 212, and 213, or equivalent. In rare cases, other courses may satisfy the requirement with department approval.

Requirements for the Minor

The department offers two minors, physics and astronomy. Students considering one of these minors should work with a faculty member in the physics department as the minor is being planned, since some courses are not offered every year.

Requirements for the Physics Minor

The program for a minor in physics consists of the following:

- PHYS 140, 131 or 141, 145, 146, 240 and 241. PHYS 130 and 135 and their co-requisite labs may be substituted for 140 and 145 with permission of the department chair.
- Additional 1 unit/8 semester hours selected from physics courses numbered above PHYS 220, of which no more than 0.50 unit/4 semester hours may be from Research in

Physics (PHYS 221/PHYS 222). (Note: All courses in physics numbered above 220 have as prerequisites PHYS 140 and 145 and MATH 111 and 112, unless otherwise noted).

This minor is open to students with all majors, but it may be especially attractive to students in disciplines that have strong ties to physics, such as chemistry, mathematics and biology. Other combinations of introductory courses may also be acceptable.

Requirements for the Astronomy Minor

The program for a minor in astronomy consists of the following:

- 1 unit/8 semester hours of 100-level courses that cover topics in astronomy from among PHYS 101, 105, 106, 107 and 109;
- A year of introductory physics with lab: PHYS 130 and 135 or 140 and 145; 131 or 141; 136 or 146.
- An additional 0.5 units/4 semester hours selected from all physics courses (see suggestions below).

There are several options for the fifth course. While any of the 100-level courses could be used, specific intermediate courses accessible upon completion of the introductory sequence with lab are also good choices. For example, PHYS 240 and 241 provide further experience with the foundations of physics. PHYS 270 explores computational approaches to problem-solving using examples from astronomy, physics and other sciences. Other options may include individual study and special-topics courses related to astronomy.

Note: College policy prohibits a student from receiving a minor in the same department as his or her major. Thus, a physics major may not elect to minor in astronomy.

Advice for First Year Students

Need help deciding which courses in the Physics Department are best suited to your background and interests? The most important questions to ask yourself in choosing a physics course at Kenyon are:

- What particular topics in physics interest me?
- Am I likely to take more physics after this year?

The answers to these questions will help you determine whether you want to take an introductory survey of physics or one of the many "general interest" courses offered by the department. Introductory surveys cover a wide range of topics and can prepare you for further study in the discipline. General interest courses focus on a specific topic such as astronomy or geology; they don't directly lead into intermediate-level physics courses.

General Interest Physics Courses

General interest physics courses are designed to be accessible to any Kenyon student. They typically do not involve as much mathematical work as the introductory survey courses, nor do they prepare students for entry into intermediate-level physics courses. All of these courses involve some laboratory work and can be used to fulfill the distribution requirement in the Natural Sciences division. Some (but not all) of these courses can be used to fulfill the collegiate requirement for coursework involving quantitative reasoning (designated "QR" courses); see the Course Catalog for descriptions and scheduling details, including which courses are being offered in upcoming semesters.

- Physics 100 (A Certain Slant on Light)
- Physics 101 (Rocket Science)
- Physics 102 (Good Nukes, Bad Nukes)
- Physics 103 (Creating with Gadgets - 0.25 units)
- Physics 104 (Einstein)
- Physics 105 (Unifying Ideas in Physics)
- Physics 106 (Astronomy: Planets and Moons)
- Physics 107 (Astronomy: Stars and Galaxies)
- Physics 108 (Geology)

- Physics 109 (Origins)

Introductory Surveys of Physics

We offer two introductory surveys of physics. For first- or second-year students who are possible physics, mathematics, or chemistry majors or who may wish to take further courses in physics, the recommended sequence is Physics 140 (Classical Physics), Physics 145 (Modern Physics) and Physics 240 (Fields and Spacetime) plus their co-requisite lab courses. These courses provide a complete survey of physics in three semesters, which is the norm in introductory level physics for physical science and engineering students at most universities. For upper-level students, particularly pre-medical students, there is a more compressed survey of physics available: Physics 130 (General Physics I) and Physics 135 (General Physics II). This sequence is only appropriate for upperclass students, due to its quicker pace. No first-year students are permitted to enroll in these courses

All of these courses have required labs; one may not register for the course without also registering for a section of the co-requisite lab. The co-requisite course for:

- Physics 140 is either Physics 141 (first-years) or Physics 131 (upper-class students)
- Physics 145 is Physics 146
- Physics 240 is Physics 241
- Physics 130 is Physics 131
- Physics 135 is Physics 136

Physics 140 also has a co-requisite of Math 111 (Calculus 1) or its equivalent, since some calculus will be used in the lectures. Physics 145 has a co-requisite of Math 112 (Calculus 2), and Physics 240 has a co-requisite of Math 213 (Calculus 3), for the same reason.

Physics 141 (First Year Seminar in Physics) is designed to introduce entering students to an area of contemporary physics research. The topic varies from year to year; in the past, the seminar has explored topics such as material science, nanoscience, astrophysics, particle physics, biological physics and gravitation. We strongly recommend this course for first-year students considering physics as a major; it is open ONLY to first-year students enrolled in or holding credit for Physics 140. It is the co-requisite lab for first-year students enrolling in Physics 240 due to advanced placement in physics and calculus (see below).

Co-requisite lab courses associated with all of the introductory physics courses provide students with opportunities to perform hands-on, quantitative explorations of physical principles related to their co-requisite courses.

Advanced Placement in Physics

Students with C-level AP Physics credit (i.e. those who scored either 4 or 5 on the Mechanics-C exam) may be eligible to enroll in Physics 240 (Fields and Spacetime) instead of Physics 140 in the fall semester, depending on the amount of experience the student has had in laboratory work and the calculus placement level of the student. Such students would then continue in physics by taking Physics 145 (Modern Physics) and 146 (Modern Physics Laboratory) in the spring semester. Several first-year students have successfully followed this route. Please note that first-year students who are permitted to take Physics 240 must also take Physics 141 (First-Year Seminar in Physics) as their co-requisite lab. Those continuing in physics beyond the first year would then take Physics 241 (Fields and Spacetime Laboratory) in their second year, after completing Physics 145 and 146. If you are interested in this option, please contact the Physics Department chair.

If you have any further questions about the courses or about what might be the best choice for you, please contact the department chair for advice.

Senior Capstone

The Senior Capstone includes the presentation of a talk on a topic in physics at a department colloquium and a set of gateway examinations in physics.

More information about the Senior Capstone in physics is available on the department website.

Physics Senior Capstone Requirements (updated July 2023)

- Passing four gateway exams administered using Moodle during proctored sessions throughout the fall and first two-thirds of the spring semester (multiple attempts are typical) and

- Giving a satisfactory public presentation explaining the physics of a topic not already covered in one of our courses, followed by an oral on the topic.

Gateways may be taken starting in late August and must be finished by the deadlines indicated below or you will risk not graduating. Talk topics must be submitted during the fall semester for presentations in February.

Detailed Description

The senior capstone in physics consists of two parts. To pass the senior capstone, students must earn a passing grade on both parts. The first part is a set of physics gateway exams, designed for students to show competency in core areas of the physics curriculum. The second is a public talk and follow-up interview, designed to assess students' ability to communicate physics above the introductory level.

There are four gateway exams, covering fundamental topics from our core coursework. The gateway exams assess mastery of physics concepts by allowing students to attempt and re-attempt each of the exams until they achieve a passing score. The areas of the exams are:

1. **Newtonian Mechanics:** kinematics, dynamics, rotational motion, oscillations, and waves.
2. **Quantum and Nuclear Physics:** modern physics, elementary quantum mechanics, spectroscopy, nuclear and particle physics.

3. **Electricity and Magnetism:** charges, electric forces and fields, magnetic forces and fields, and special relativity.
4. **Experimental and Computational Physics:** circuits, optics, data analysis, experimental uncertainty, instrumentation, and methods of computational physics.

Taken together, these exams encompass the material covered by our four-semester introductory sequence (Phys 140, 145, 240, 245) plus fundamentals from our upper-level lab courses in computation, electronics, and experimental physics (Phys 270, 380, 385).

In their public talks, students present a 25-minute talk on a topic for which they have explored the underlying physics through literature (and sometimes laboratory) research. Each student proposes a topic to the department, based on which they are assigned a talk advisor. Senior capstone talks are typically given in the spring semester during a Saturday Physics Symposium or one of our Friday colloquium slots. Physics faculty conduct a follow-up interview with each student within about a week of their public talk, to gauge the student's depth of understanding of the physical principles and analytic aspects of their topic.

Together, the talk and the interview afford students the opportunity to integrate and apply elements of their physics education by making an independent study of a physics topic — researching unfamiliar aspects of the topic, identifying and organizing key concepts, applying appropriate analyses based on their course work in physics, and communicating clearly and effectively the context and the explanation of their topic to others.

The department and the College consider the senior capstone a valuable learning experience and hope that students will value it as well. It has frequently been noted by Kenyon physics alumni as an important element and asset in job and grad school interviews. It is a significant undertaking, providing a significant sense of accomplishment when successfully completed.

In a few instances, students have interpreted the low failure rate of the senior capstone as an indication that passage is guaranteed. That is not the case; putting in consistent effort and consulting closely with physics faculty (especially the talk advisor) as one works through the capstone elements is the surest way to avoid retakes and failure to graduate on time.

Specifics for the Gateway Exams

Gateway exams will be completed electronically, using Moodle. Each gateway exam will consist of eight questions, with a time limit of 50 minutes. Question types include multiple choice and numerical answer (with provisions for grading the units on an answer). When a student takes a gateway exam, the software will generate an exam drawn from a large bank of questions; thus, students will be able to take each exam multiple times without significant overlap in questions. Students will be notified by the gateway administrator when they have met or exceeded the threshold score deemed by the physics faculty as passing for each exam. The number of times a student may attempt each gateway is not limited, except by the final deadlines given below. Indeed, students are not expected to pass every gateway exam on their first attempt.

By the end of the first full week of fall semester, the department chair or another designated faculty member will identify dates for offering gateway exam opportunities and share them with all eligible students (those with senior standing). Students must bring their physics-issued laptop to the exam and a writing implement to each gateway attempt. Students may also bring an ordinary calculator (phone and other internet-capable calculators are not allowed), or they may borrow one of the department's stock to use during their gateway attempt. Equation sheets will be distributed during the test and must be returned, with any scratch paper used, upon completing the gateway attempt. Students with testing accommodation arrangements through Student Accessibility and Support Services (SASS) should notify the gateway administrator of appropriate accommodations in advance of the gateway opportunities. No accommodations will be made without appropriate documentation from SASS.

To fulfill requirements for the gateway portion of the senior capstone, students must:

- complete the Newtonian Mechanics and Quantum & Nuclear Physics gateway exams before the end of the fall semester.

- complete the Electromagnetism and Experimental & Computational Physics gateway exams before the end of the tenth week of the spring semester.

If a student has not passed one or more of the gateway exams by the designated deadline, that student will be deemed to have failed the first attempt at this portion of the senior capstone, per college guidelines regarding senior capstones. Students in this position will be given a last-chance opportunity to pass the remaining gateways during the first week of spring semester (for either of the fall gateways) and during the twelfth week of spring semester (for either of the spring gateways).

Preparing for the Gateway Exams

While the gateway exams are not standardized tests, they are still administered electronically and are, therefore, somewhat different from the usual exams one finds in the Kenyon physics department. Therefore, it is important that students spend some time preparing both for the content of the exam and for its mode of delivery. For each of the four gateway exams, students will find on Moodle a guide that can help to direct their study as well as a sample electronic test consisting of a limited set of questions culled from the database of gateway questions for that exam. Students should familiarize themselves with these documents and practice taking the sample exam before attempting the corresponding gateway exam.

These instruments are able to test certain types of knowledge and skills, including familiarity with content and the relationships between various quantities and their mathematical dependencies. Because of this, you might expect to get by with many fewer full calculations than you would perform on other types of tests, especially if you consciously and consistently try to apply the following types of reasoning:

- looking at extreme cases: what happens when a variable goes to zero or infinity?
- applying powerful ideas such as conservation laws or symmetry
- examining the dimensions (units) to help figure out a relationship

- thinking about proportionalities: kinetic energy goes like velocity squared, while momentum goes like velocity
- making order of magnitude estimates, thereby saving time taken to calculate exactly
- knowing the typical size of some physical quantities and effects — e.g., wavelength of visible light, thermal energy at room temperature, ionization energy for atomic hydrogen, etc.

These techniques can help you zero in on the correct answer without writing out a detailed solution and help you to eliminate wrong answers quickly, giving you a basis for choosing a best answer from those remaining.

Specifics for the Public Talk and Interview

Typically, senior capstone talks (except for honors and research talks; see below) will be presented during the first half of the spring semester. Each student must present on a unique topic in a given year. The selection of topics is on a first-come, first-served basis. Students must propose a topic in writing to the department chair no later than the last day of classes in the fall semester. Department faculty will confer shortly after this deadline to assign each student a talk advisor. Students must confer with their talk advisor as they prepare their talk. Students are expected to give a practice talk to their advisor no later than 48 hours before their scheduled presentation time. Approval to present at the scheduled colloquium or symposium is contingent upon the talk advisor’s confirmation that appropriate consultation and preparation has occurred.

Students who are pursuing honors research with a faculty member during their senior year are required to present a 50-minute honors proposal talk at a physics colloquium early in the fall semester. Successful completion of that talk and the interview following it will fulfill the oral portion of the senior capstone requirement for those students. Requirements for consulting with their talk advisor (= their honors advisor) are the same as those specified above.

Students who have completed a summer-long research project in physics either at Kenyon or elsewhere during the summer immediately prior to their senior year may be invited to give a regular (50 minute) or shortened (25 minute) talk describing the physics underlying their research project. Such talks will be scheduled during the fall semester of the senior year. Each student invited to give a fall talk will be assigned a Kenyon faculty member as their talk advisor. Requirements for consulting with their talk advisor are the same as those specified above. To allow time for this consultation to take place, no research project talk (except for honors talks) will be scheduled prior to the third week of the fall semester.

Follow-up interviews for each talk will be scheduled during the week following the talk (in the case of a colloquium talk) or later in the day (in the case of a Physics Symposium talk). These interviews will be about 20 minutes long (30 minutes, for honors candidates). During these interviews, physics faculty will ask the student questions related to their talk, particularly focusing on the foundational physical aspects of their topic and the analytical element presented in their talk.

Preparing for the Public Talk and Interview

Senior capstone talks in physics should have a scholarly source (journal article or similarly authoritative source) as their basis. To prepare your presentation, start by reading your source article carefully, picking through it to understand what it has to say, at root. Identify the main thrust of the argument laid out in the article and restate it as clearly and concisely as you can. Next, examine the evidence (especially any graphs, diagrams, tables, or figures) being used to support that argument. Then, you need to connect that argument to concepts and resources outside the paper itself - look for additional references (articles, textbooks, etc.) which help you explain the physical concepts employed in the paper, the context in which the paper should be understood, and the connection of the paper to material you have learned in one or more of your physics courses. In particular, each presentation should include at least one substantial chunk of analytical physics — a derivation, integration, calculation, model, or other application of appropriately rigorous mathematical and physical analysis to the problem at hand.

Once you have identified and digested these additional resources, use them and the original paper to prepare a 25-minute oral presentation in which you explain in your own words the physics which you identified as being the point or the heart of the paper. Your presentation may be in one of a number of formats — chalkboard lecture, PowerPoint, Keynote, or perhaps a combination of formats. The department strongly encourages you to avoid substituting glitz for content, however. We will be judging the strength of the physical insight and the clarity of the physical and mathematical explication you bring to bear on your topic, not your facility with computer graphics and animation!

It is vital that you work closely with your faculty advisor as you prepare your talk. They can help you understand the criteria by which your talk will be judged. Be sure to tell your advisor if achieving distinction is one of your goals.

Whatever the format, you should practice your presentation out loud for a small audience (your advisor, a friend, anyone) at least twice, in full, before you give it at the departmental colloquium or symposium. It should fill the 25-minute time-slot — it will create a poor impression if you do not prepare enough material, and we will simply cut you off if you prepare too much material to cover in that time. Only by practicing your finished presentation will you know for sure how long it will take. You should also be prepared to take questions from the audience at the end of your presentation.

The follow-up interview will give you a chance to convey deeper understanding of the analytical part of your talk and the physics that underlies it in response to questions from faculty members. The questions will be motivated by your talk topic and content. You should not need to prepare supplemental slides or other visual aids; you will be asked to bring your presentation slides to the interview in case there are questions for which viewing the slides would be beneficial. You will also very likely be asked to use the chalkboard in answering some questions — perhaps by sketching a graph, examining a mathematical expression from your talk, or thinking through how some units or an equation related to your topic works. Knowing what underlies your topic and giving thought to how to explain it will be the best preparation for this part of the capstone.

Final Remarks

The purpose of the senior capstone requirement at Kenyon is for each graduating senior to complete a significant body of work in which they apply the knowledge and skills gained in their major course of study. It provides an opportunity to synthesize and consolidate ideas, to practice skills, and to construct personal relevance and ownership from your studies as you transition to the next stage of your career and life. It should be an exercise that stretches you, in a good way — helping you make connections and realizations you could not make in individual courses. We believe that our senior capstone helps our majors accomplish these goals, and we look forward to celebrating with you all once you have achieved them!

Honors

Honors work in physics involves directed research on a specific topic in experimental, theoretical or computational physics, culminating in a written thesis, an oral presentation at a departmental colloquium and an examination by an outside specialist.

More information about honors work in physics is available on the department website.

Honors Program in Physics

Updated Oct. 2024

Honors work in physics at Kenyon involves directed research on a topic of contemporary importance in some subfield of physics, through which the honors candidate pursues intensive, individual, potentially publishable research, learning to conduct research and communicate the results at a professional level.

Each student working toward honors in physics is mentored by an on-campus faculty research advisor. Typically, this is a member of the physics faculty, although in some cases the on-campus research mentor may be a member of a closely related department. Any honors project needs to be collaboration between the student and the faculty mentor on the faculty mentor's research.

To assure adequate time for the proposed research, honors candidates enroll in the one-unit, year-long course sequence PHYS 497-498 – Senior Honors. In order to enroll in PHYS 497-498, students must have the strong support of their proposed research mentor and they must meet or exceed the collegiate minimum cumulative GPA for pursuing honors (or the department must successfully petition on behalf of the student for an exception to that minimum cumulative GPA). Honors students must also complete the senior capstone experience in physics; however, certain aspects of the senior capstone are modified or subsumed within the requirements for honors, as outlined below.

Requirements of the Honors Program in Physics

- Present a 50-minute talk (the "honors proposal") at a departmental colloquium within the first five weeks of the semester and complete an oral interview with physics faculty within a few days of that talk. Part of this talk stands as the capstone talk for the major. The talk should allow for a few minutes of questions from the audience.
- Complete all four gateway exams for the senior capstone in physics by the end of the fall semester.
- Conduct a supervised research project on a topic of contemporary importance in physics.
- Submit a written thesis detailing the research project by mid-April of the spring semester.
- Complete an oral examination by an outside examiner who is a specialist in the area of research covered by the project.

The Honors Proposal

This 50-minute talk serves to introduce the proposed topic of research and describe the specific project to be undertaken. The first half of the talk should be dedicated to a pedagogical introduction to the research area. This portion of the talk and associated oral exam will satisfy the talk and interview requirement for the senior capstone in physics and will be assessed using the same standards as those capstone talks. In preparing this part of their talks, honors candidates may find the advice on the senior capstone page of the department website helpful.

The remainder of the talk should build toward and outline the proposed honors research. Based on this portion of the talk and interview, department faculty will evaluate whether the proposed research is consistent with the goals of the honors program, including being of appropriate scope for a one-unit, year-long course at the senior level, having the potential to contribute to a publishable research result, being within the capability of the candidate to complete successfully, and having the support of a research mentor with the resources of time and expertise to guide the project.

Note that the early date for this honors proposal talk means that students should begin preparing for honors work in the spring of their junior year, collaborating with a potential research mentor to identify a project. Typically, honors candidates will work within a faculty mentor's research program during the summer prior to their senior year.

Gateway Exams

Completing all four gateway exams by the end of the fall semester provides time in the spring semester for the honors candidate to focus on completing their research project and communicating their results in a well-written honors thesis. If a candidate does not complete all four gateways by the end of the fall semester, they will have a last-chance opportunity to complete all remaining gateways during the first week of the spring semester. A student who does not complete the gateways by that time may elect to continue their research project through registration in PHYS 390 – Research in Physics.

The Anatomy of a Thesis

A thesis authored by the honors candidate is required to achieve honors in physics. Writing the thesis allows the honors candidate to (1) introduce and describe the foundations of the field of study, (2) demonstrate knowledge of the tools and methods used to conduct the research, and (3) synthesize and report the results of the project. Therefore, the thesis should be organized into three sections (each of which may contain any number of chapters):

- Section 1: The introductory section should include the motivation for the project as well as the foundational information needed to put the research project in context. This section should be readable, and comprehensible, by any faculty member of the department.
- Section 2: The tools and methods section should describe the research methods being used by the candidate to conduct the research project. This section should be accessible to faculty in the department who, regardless of subfield, use similar methods in their work (e.g. computational methods, experimental methods, or theoretical methods).
- Section 3: The results section of the thesis is reserved for the technical aspects and outcomes of the project and therefore may necessarily be written in such a way that it is accessible only to a limited number of members of the department and the external examiner.

All faculty in the department will be given the opportunity to read each honors thesis. While most members of the department will focus their feedback on the first (and possibly second) sections of the thesis, the research mentor, the external examiner, and one other designated member of the department (the "internal examiner") will be responsible for reading the entirety of the thesis in preparation for the oral exam.

Oral Examination

Early in the outside examiner’s visit, the candidate will have a one-on-one conversation with the examiner, during which the candidate will give the examiner a “tour” of the honors research project — apparatus, code, graphs, and other results, as appropriate — to acquaint the examiner with the candidate’s perspective on and command of the project details. The conversation will typically last about 30 to 40 minutes; it should not last longer than 60 minutes. Following that conversation, the candidate will stand for an oral examination conducted by the external examiner. All department faculty will be invited to the oral examination; at minimum, the research mentor and the internal examiner must attend.

The candidate will be instructed to bring a laptop on which they can display the pdf version of their honors thesis, in case any questions relate to graphs, code, or other figures from the thesis. The first question addressed to the candidate will be “Explain the main result of your work.” While the external examiner is responsible for leading the oral examination, any faculty member present is welcome to participate by posing or following up on questions during the exam. The oral will typically last about 60 minutes; it may not last longer than 90 minutes.

Level of Honors

Following the oral examination, the level of honors will be determined by the external examiner, based on their assessment of the three major elements of the honors process — the candidate’s work on the research itself, the written thesis describing that work, and the candidate’s oral communication of ideas during the external examiner’s visit, focusing particularly on their ability to reason through questions during the oral examination. To earn highest honors, the candidate must distinguish themselves on all three elements of the process, while high honors or honors will be earned by those who distinguish themselves on two or one of those elements, respectively. While department faculty may offer context and advice, determination of the level of honors is, in the end, the purview of the external examiner.

Titles of recent honors theses include:

- "Approximate cloning of quantum entanglement"
- “Learning from Star Shadows: Investigating an Activity Cycle on Eclipsing Binary Star FL Lyr”
- “Numerical Simulations of Nonlinear Physics in the Universe”
- “Coherent Control of Processes That Break the Dipole Blockade”
- “PAC-MANN: A PulsAr Classifier — Machine-learning Algorithm with Neural Networks”
- “Simulating the high-energy Universe, from the Big Bang to black holes”

Courses in Physics

The Kenyon College faculty voted to change from Kenyon units to semester hours. This change will go into effect for all students who start at the College in the fall of 2024. Both systems will be used throughout the course catalog with the Kenyon units being listed first.

A Certain Slant on Light

PHYS 100 CREDITS: 0.5/4 QR

For many centuries, both scientists and artists have pondered the myriad compositions of light, including rainbows, shadows, colors and mirages. While the beauty of these phenomena is fascinating, it is also rewarding to grapple with the underlying theory that explains them. In this course, students explore how light can be modelled as a ray, wave or particle, and use these ideas to explain concepts such as reflection, refraction, scattering, diffraction and absorption. Several in-class laboratory exercises strengthen the conceptual understanding of light. Throughout the course, the focus is to explain various phenomena, ranging from fiber-optic technology to pointillism. A final project, which synthesizes the conceptual understanding of light, is required, and students are encouraged to follow their interests, through various forms, in order to fulfill it. While the course has some mathematical content -- simple algebra and geometry -- it is open to any student and does not count toward the physics major. No prerequisite.

Rocket Science

PHYS 101 CREDITS: 0.5/4 QR

"Rocket science" may be proverbial as a complex subject impossible for the ordinary person to understand, but in fact its essential principles are entirely accessible to any Kenyon student. Our course explores the basic concepts of rocket propulsion and space flight, including Newton's laws of motion, ballistics, aerodynamics, the physics and chemistry of rocket motors, orbital mechanics and beyond. Simple algebra, numerical calculations and data analysis help us apply the principles to real situations. We also delve into the history of astronautics, from the visionary speculations of Tsiolkovsky and Goddard to the missiles and space vehicles of today. Finally, we take a look at some of the developments in technology and space exploration that may lie just around the corner. In addition to the regular class meeting, there are several evening and weekend lab sessions, during which we design, build, test and fly model rockets powered by commercial solid-fuel engines. A willingness to build upon high school science and mathematics is expected. This course does not count toward the physics major. No prerequisite.

Good Nukes, Bad Nukes

PHYS 102 CREDITS: 0.5/4 QR

Nuclear power produces needed energy, but nuclear waste threatens our future. Nuclear weapons make us strong, but dirty bombs make us vulnerable. Nuclear medicine can cure us, but nuclear radiation can kill us. Radiocarbon dating tells us about the past, but it can challenge religious faith. This course is designed to give each student the scientific knowledge necessary to understand and participate in public discussions of nuclear issues. The concepts include classification of nuclei; the types of energy (radiation) released in nuclear reactions; the interactions of that radiation with matter, including human health effects; and the design of nuclear reactors and nuclear weapons. Hands-on demonstrations and experiments explore radioactive decay, antimatter, transmutation of atoms, nuclear detectors and interactions of radiation with matter. We apply the core concepts to understanding contemporary issues, such as electric power generation using nuclear energy, including its environmental effects; advances in nuclear medicine; the challenges of preventing nuclear weapons proliferation; the threat of "dirty bombs"; and dating the universe. We also cover the history of the Manhattan Project and the use of nuclear weapons that brought an end to World War II. The course offers a field trip to at least one significant nuclear site in Ohio. This course is open to any student and does not count toward the physics major. No prerequisite.

Creating with Gadgets

PHYS 103 CREDITS: 0.25/2

In this course, students learn to use motors, relays, microcontrollers and electronic components to design and build computer-controlled devices, small robots and interactive gizmos increasingly employed in projects by artists, designers and scientists. The primary tool is the Arduino open source microcontroller environment. Developed for use by designers, artists and hobbyists, the Arduino environment provides a wide array of options for implementing automation and interaction between a physical device and its environment. It is used in applications ranging from interactive installation art to smart home technologies and hardware control in scientific applications. The course combines laboratory exercises, homework assignments, individual and group project work, and a culminating public presentation. The course does not count toward the physics major. No prerequisite.

Einstein

PHYS 104 CREDITS: 0.5/4 QR

Over 100 years ago, Albert Einstein helped launch a far-reaching revolution in physics. His relativity theories are justly famous, but he also made amazing discoveries about quantum mechanics and the statistical properties of matter and radiation. This course focuses on Einstein's life, his scientific contributions and his role in the creation of modern physics. We find that his insights are significant not just for microscopic particles or distant galaxies, but also for the phenomena of everyday life. Lectures, discussions and readings (including Einstein's own works) are supplemented by laboratory experiments. The course has some mathematical content -- simple algebra and geometry -- and is open to any student and does not count toward the physics major. No prerequisite.

Frontiers of Gravity

PHYS 105 CREDITS: 0.5/4 QR

Gravity is at once the most familiar and most mysterious of the basic forces of nature. It shapes the formation, structure and motion of stars, galaxies and the cosmos itself. Also, because gravity affects everything, it enables us to investigate parts of the universe that are otherwise invisible to us. This course explores the role of gravity in a few vibrant areas of contemporary astrophysics: the search for planets beyond our solar system, the discovery of giant black holes in the nuclei of galaxies, the generation and detection of gravitational waves, and the evidence for dark matter and dark energy in our universe. In addition to the scheduled class lectures and discussions, students are required to meet a few times during the semester for evening laboratories. This course does not count toward the physics major. No prerequisite.

Astronomy: Planets and Moons

PHYS 106 CREDITS: 0.5/4

This course introduces the modern understanding of the solar system, including planets, moons and smaller bodies (asteroids, comets, meteors). Topics include planetary interiors, surface modification processes, planetary atmospheres and the evolution of the solar system. Evening laboratory sessions utilize a variety of methods for exploring space-science topics, including telescopic observations, computer simulations and laboratory investigations. This course does not count toward the physics major. No prerequisite.

Astronomy: Stars and Galaxies

PHYS 107 CREDITS: 0.5/4 QR

This course surveys current knowledge of the physical nature of stars and galaxies. Topics include the sun and other stars, the evolution of stars, interstellar matter, the end products of stellar evolution (including pulsars and black holes), the organization of stellar systems such as clusters and galaxies, and the large-scale structure of the universe itself. Evening laboratory sessions include telescopic observation, laboratory investigations of light and spectra, and computer modeling and simulation exercises. This course does not count toward the physics major. No prerequisite.

Geology

PHYS 108 CREDITS: 0.5/4

As an introduction to the geosciences designed for all students, this course surveys a wide range of physical geology topics. Our initial coverage of minerals and rocks, the basic building blocks of the world around us, includes discussions of the environments in which they form and the major processes operating in these environments. Hands-on exercises are designed to aid in the identification of these basic components of the Earth and to teach students how to recognize clues to their formation. Students use this knowledge in a series of self-guided on-campus "field trips." Our coverage of plate tectonics includes discussions of the major evidence in support of this grand unifying theory of geology, including seismicity and earthquakes, volcanism and plutonic activity, orogenesis and structural geology, and geomagnetism and paleogeographic reconstruction. We establish these ideas in a global context and apply them to the geologic history of the North American continent. Requirements include laboratory exercises, on-campus field trips, at least one off-campus field trip and small group projects. This course does not count toward the physics major. No prerequisite.

Origins

PHYS 109 CREDITS: 0.5/4

Around us we see a vast, expanding universe of galaxies. The galaxies are composed of stars, some of them orbited by planets. At least one of these planets is inhabited by an astoundingly complex set of living things. Where did all this come from? This course presents an overview of the formation and evolution of the universe, the solar system, planet Earth and life on our planet. Astronomical observations, computer simulations and laboratory experiments supplement lectures and readings. This course does not count toward the physics major. No prerequisite.

General Physics I

PHYS 130 CREDITS: 0.5/4 QR

This course is the first in a one-year introductory physics sequence. Topics include Newtonian mechanics, work and energy, fluids, and electric fields. When possible, examples relate to life science contexts. The course combines lectures, in-class exercises, homework assignments and examinations. Knowledge of calculus is not required. This course does not count toward the physics major. Prerequisite: concurrent enrollment in PHYS 131. Sophomore standing. Offered every fall.

Introduction to Experimental Physics I

PHYS 131 CREDITS: 0.25/2 QR

This laboratory course meets one afternoon each week and is organized around weekly experiments that explore the phenomena of classical mechanics and electromagnetism, including motion, forces, fluid mechanics and conservation of energy and momentum. Lectures cover the theory and instrumentation required to understand each experiment. Experimental techniques emphasize computerized acquisition and analysis of video images to study motion. Students are introduced to computer-assisted graphical and statistical analysis of data as well as the analysis of experimental uncertainty. Except in rare instances, this course does not count toward the physics major. Prerequisite: concurrent enrollment in PHYS 130 (or PHYS 140 for sophomores enrolled in PHYS 140). Offered every fall.

General Physics II

PHYS 135 CREDITS: 0.5/4 QR
This course is the second in a one-year introductory physics sequence. Topics include wave phenomena, geometrical and physical optics, elementary quantum theory, atomic physics, X-rays, radioactivity, nuclear physics and thermodynamics. When possible, examples relate to life science contexts. The course combines lectures, in-class exercises, homework assignments and examinations. Knowledge of calculus is not required. This course does not count toward the physics major. Prerequisite: PHYS 130 and concurrent enrollment in PHYS 136. Offered every spring.

Introduction to Experimental Physics II

PHYS 136 CREDITS: 0.25/2
This laboratory course meets one afternoon each week and is organized around weekly experiments that explore the phenomena of waves phenomena, geometrical and physical optics, elementary quantum theory, atomic physics, X-rays, radioactivity, nuclear physics and thermodynamics. Lectures cover the theory and instrumentation required to understand each experiment. Students continue to develop skills in computer-assisted graphical and statistical analysis of data as well as the analysis of experimental uncertainty. This course does not count toward the physics major. Prerequisite: PHYS 131 and concurrent enrollment in PHYS 135. Offered every spring.

Classical Physics

PHYS 140 CREDITS: 0.5/4 QR
This lecture course is the first in a three-semester, calculus-based introduction to physics (PHYS 140, 145 and 240). Topics include the kinematics and dynamics of particles and solid objects; work and energy; linear and angular momentum; and gravitational, electrostatic and magnetic forces. PHYS 140 is recommended for students who might major in physics and is appropriate for students majoring in other sciences and mathematics, particularly those who are considering

careers in engineering. The course combines lectures, in-class exercises, homework assignments and examinations. This course is required for the physics major. Prerequisite: concurrent enrollment or credit for MATH 111, or equivalent, and concurrent enrollment in PHYS 141 (first-year students) or PHYS 131 (sophomore students). Open only to first-year and sophomore students. Offered every fall.

First-Year Seminar in Physics

PHYS 141 CREDITS: 0.25/2 QR

This seminar explores a significant current topic in physics that challenges first-year students. The topic varies from year to year. In the past, the seminar has explored such topics such nanoscience, astrophysics, particle physics, biological physics and gravitation. In addition to introducing the fundamental physics connected with these topics, the course exposes students to recent developments, as the topics are often closely related to the research area of faculty teaching the seminar. The seminar meets one evening a week for lectures, discussions, laboratory experiments and computer exercises. This course fulfills the concurrent laboratory requirement of PHYS 140 and serves as solid preparation for PHYS 146. It is required for the physics major. Prerequisite: first-year students who are concurrently enrolled in or have placed out of PHYS 140. Offered every fall.

Modern Physics

PHYS 145 CREDITS: 0.5/4 QR

This lecture course is the second in a three-semester calculus-based introduction to physics, focusing on the physics of the 20th century. Topics include geometrical and wave optics, special relativity, photons, photon-electron interactions, elementary quantum theory (including wave-particle duality, the Heisenberg uncertainty principle, and the time-independent Schrödinger equation), atomic physics, solid-state physics, nuclear physics and elementary particles. PHYS 145 is recommended for students who might major in physics and is appropriate for students majoring in other sciences or mathematics, particularly those who are considering careers in engineering. The course combines lectures, in-class exercises, homework assignments and examinations. Open only to first-year and sophomore students. This course is required for the physics major. Prerequisite: PHYS 140 and MATH 111 or equivalent and concurrent enrollment in PHYS 146 and MATH 112 or equivalent . Offered every spring.

Modern Physics Lab

PHYS 146 CREDITS: 0.25/2 QR

This laboratory course is a corequisite for all students enrolled in PHYS 145. The course meets one afternoon each week and is organized around weekly experiments exploring the phenomena of waves, optics, X-rays, and atomic and nuclear physics. Lectures cover the theory and instrumentation required to understand each experiment. Experimental techniques include the use of lasers, X-ray diffraction and fluorescence, optical spectroscopy, and nuclear counting and spectroscopy. Students are introduced to computer-assisted graphical and statistical analysis of data, as well as the analysis of experimental uncertainty. This course is required for the physics major. Prerequisite: PHYS 131 or 141 and concurrent enrollment in PHYS 145. Offered every spring.

Fields and Spacetime

PHYS 240 CREDITS: 0.5/4 QR

This lecture course is the third semester of the calculus-based introductory sequence in physics, which begins with PHYS 140 and PHYS 145. Topics include electric charge, electric and magnetic fields, electrostatic potentials, electromagnetic induction, Maxwell's equations in integral form, electromagnetic waves, the postulates of the special theory of relativity, relativistic kinematics and dynamics, and the connections between special relativity and electromagnetism. It may be an appropriate first course for particularly strong students with advanced placement in physics and mathematics; such students must be interviewed by and obtain permission from the chair of the physics department. This course is required for the physics major. Prerequisite: PHYS 140 or equivalent and concurrent enrollment in PHYS 241 (upper-class students) or PHYS 141 (first-years) and MATH 213 or equivalent. Offered every fall.

Fields and Spacetime Laboratory

PHYS 241 CREDITS: 0.25/2 QR

This laboratory course is a corequisite for all upperclass students enrolled in PHYS 240. The course is organized around experiments demonstrating various phenomena associated with the special theory of relativity and electric and magnetic fields. Lectures cover the theory and instrumentation required to understand each experiment. Laboratory work emphasizes computerized acquisition and analysis of data, the use of a wide variety of modern instrumentation and the analysis of experimental uncertainty. This course is required for the physics major. Prerequisite: PHYS 146 and concurrent enrollment in PHYS 240. Offered every fall.

Oscillations and Waves

PHYS 245 CREDITS: 0.5/4 QR

The topics of oscillations and waves serve to unify many subfields of physics. This course begins with a discussion of damped and undamped, free and driven, and mechanical and electrical oscillations. Oscillations of coupled bodies and normal modes of oscillations are studied along with the techniques of Fourier analysis and synthesis. We then consider waves and wave equations in continuous and discontinuous media, both bounded and unbounded. The course may also treat properties of the special mathematical functions that are the solutions to wave equations in non-Cartesian coordinate systems. This course is required for the physics major. Prerequisite: PHYS 145 and 240. Offered every spring.

Introduction to Computational Physics

PHYS 270 CREDITS: 0.5/4 QR

As modern computers become more capable, a new mode of investigation is emerging in all science disciplines using computers to model the natural world and solving model equations numerically rather than analytically. Thus, computational physics is assuming co-equal status with theoretical and experimental physics as a way to explore physical systems. This course introduces students to a variety of computational methods, which could include the methods of computational physics, numerical integration, numerical solutions of differential equations, Monte Carlo techniques and discrete Fourier transforms. Students learn to implement these techniques in the computer language C, a widely used high-level programming language in computational physics. For some techniques, students may also learn implementations in the computer language Python. In addition, the course expands students' capabilities in using a symbolic algebra program (*Mathematica*) to aid in theoretical analysis and in scientific visualization. This course is required for the physics major. Prerequisite: PHYS 240 and MATH 112 or equivalent. Offered every spring.

Research in Physics

PHYS 310 CREDITS: 0.25/2

In this course students will conduct research, synthesize and share experiences, attend professional presentations in the department, and present their research with oral and written presentations. Students will complete a minimum of three hours of independent research under the supervision of a faculty member as well as participate in discussion sections and other commitments as designed by the instructor. This course does not count toward any major requirement. Permission of instructor required. Offered every semester. No prerequisite.

Research in Physics

PHYS 311 CREDITS: 0.5/4

In this course students will conduct research, synthesize and share experiences, attend professional presentations in the department, and present their research with oral and written presentations. The time commitment for students is six to eight hours of individual research under the supervision of a faculty member. This section represents a significant commitment to a research project. Enrollment in this section requires consultation with the department chair. This course does not count toward any major requirement. Permission of instructor required. Offered every semester. No prerequisite.

Classical Mechanics

PHYS 340 CREDITS: 0.5/4 QR

This course begins by revisiting most of the Newtonian mechanics learned in introductory physics courses but with added mathematical sophistication. A major part of the course is spent understanding an alternate description to that of the Newtonian picture: the Lagrange-Hamilton formulation. The course also covers the topics of motion in a central field, classical scattering theory, motion in non-inertial reference frames and dynamics of rigid body rotations. This counts toward the theoretical elective for the major. Prerequisite: PHYS 245 and MATH 213. Offered every other fall.

Astrophysics and Particles

PHYS 345 CREDITS: 0.5/4 QR

From particle accelerators to galaxies and stars to the big bang, high-energy particle physics and astrophysics address the sciences' most fundamental questions. This course covers topics of contemporary relevance from the combined fields of cosmology, astrophysics, phenomenological particle physics, relativity and field theory. Topics may include the big bang, cosmic inflation, the standard model of particle physics, an introduction to general relativity, and the structure and evolution of stars and galaxies' stellar structure and galactic evolution. This counts toward the theoretical elective for the major. Prerequisite: PHYS 350. Offered every other spring.

Electricity and Magnetism

PHYS 350 CREDITS: 0.5/4 QR

In this course we develop further the basic concepts of electricity and magnetism previously discussed in PHYS 240 and introduce mathematical techniques for analyzing and calculating static fields from source distributions. These techniques include vector calculus, Laplace's equation, the method of images, separation of variables and multipole expansions. We revisit Maxwell's equations and consider the physics of time-dependent fields and the origin of electromagnetic radiation. Other topics include the electric and magnetic properties of matter. This course provides a solid introduction to electrodynamics and is a must for students who plan to study physics in graduate school. This counts toward the theoretical elective for the major. Prerequisite: PHYS 245 and MATH 213. Offered every other fall.

Optics

PHYS 355 CREDITS: 0.5/4 QR

The course begins with a discussion of the wave nature of light. The remainder is concerned with the study of electromagnetic waves and their interactions with lenses, apertures of various configurations and matter. Topics include the properties of waves, reflection, refraction, interference, and Fraunhofer and Fresnel diffraction, along with Fourier optics and coherence theory. This counts toward the theoretical elective for the major. Prerequisite: PHYS 350. Offered every other spring.

Quantum Mechanics

PHYS 360 CREDITS: 0.5/4 QR

This course presents an introduction to theoretical quantum mechanics. Topics include wave mechanics, the Schrödinger equation, angular momentum, the hydrogen atom and spin. This counts toward the theoretical elective for the major. Prerequisite: PHYS 245 and MATH 213. Offered every other fall.

Quantum Mechanics II

PHYS 365 CREDITS: 0.5/4 QR

This course extends the formalism of quantum mechanics and applies it to a variety of physical systems. Topics covered may include atomic and molecular spectra, nuclear structure and reactions, NMR, scattering, perturbation theory, quantum optics, open-system dynamics and quantum entanglement. This counts toward the theoretical elective for the major. Prerequisite: PHYS 360. Offered every other spring.

Thermodynamics and Statistical Mechanics

PHYS 370 CREDITS: 0.5/4 QR

This introduction to thermodynamics and statistical mechanics focuses on how microscopic physical processes give rise to macroscopic phenomena; that is, how, when averaged, the dynamics of atoms and molecules can explain the large-scale behavior of solids, liquids and gases. We extend the concept of conservation of energy to include thermal energy (heat) and develop the concept of entropy for use in determining equilibrium states. We then apply these concepts to a wide variety of physical systems, from steam engines to superfluids. This counts toward the theoretical elective for the major. Prerequisite: PHYS 245 and MATH 213. Offered every other fall.

Condensed Matter Physics

PHYS 375 CREDITS: 0.5/4 QR

Modern field theories may find their inspiration in the quest for understanding the most fundamental forces of the universe, but they find crucial tests and fruitful applications when used to describe the properties of the materials that make up our everyday world. In fact, these theories have made great strides in allowing scientists to create new materials with properties that have revolutionized technology and our daily lives. This course includes crystal structure as the fundamental building block of most solid materials; how crystal lattice periodicity creates electronic band structure; the electron-hole pair as the fundamental excitation of the "sea" of electrons; and Bose-Einstein condensation as a model for superfluidity and superconductivity. Additional topics are selected from the renormalization group theory of continuous phase transitions, the interaction of light with matter, magnetic materials and nanostructures. There will be a limited number of labs on topics such as crystal growth, X-ray diffraction as a probe of crystal structure, specific heat of metals at low temperature, and spectroscopic ellipsometry. This counts toward the theoretical elective for the major. Prerequisite: PHYS 360. Offered every other spring.

Electronics I

PHYS 380 CREDITS: 0.25/2 QR

This course builds upon the foundation developed in PHYS 240 and 241 for measuring and analyzing electrical signals in DC and AC circuits, introducing students to many of the tools and techniques of modern electronics. Familiarity with this array of practical tools prepares students for engaging in undergraduate research opportunities as well as laboratory work in graduate school or industry settings. Students learn to use oscilloscopes, meters, LabVIEW and various other tools to design and characterize simple analog and digital electronic circuits. The project-based approach used in this and associated courses (PHYS 381 and 382) fosters independence and creativity. The hands-on nature of the labs and projects helps students build practical experimental skills including schematic and data-sheet reading; soldering; interfacing circuits with measurement or control instruments; and troubleshooting problems with components, wiring and measurement devices. In each electronics course, students practice documenting work thoroughly, by tracking work in lab notebooks with written records, diagrams, schematics, data tables, graphs and program listings. Students also engage in directed analysis of the theoretical operation of components and circuits through lab notebook explanations, worksheets and occasional problem sets. Students may be asked to research and present to the class a related application of the principles learned during investigations. This course is required as part of the 1.00 unit of upper-level experimental physics coursework to complete the major in physics. Prerequisite: PHYS 240. Offered every fall and runs only the first half of the semester.

Electronics II

PHYS 381 CREDITS: 0.25/2 QR

In this course, students explore circuit design and analysis for active and passive analog circuit elements, from the physics of the components (semiconductor diodes, transistors) to the behavior of multi-stage circuits. Experiments explore transistors, amplifiers, amplifier design and frequency sensitive feedback networks. This counts toward the experimental elective for the major. Prerequisite: PHYS 380 (may be taken in the same semester). Offered in alternate years and runs only the second half of the fall semester.

Electronics III

PHYS 382 CREDITS: 0.25/2 QR

In this course, students explore applications of integrated circuits (ICs), the fundamental building blocks of electronic devices such as personal computers, smart phones and virtually every other electronic device in use today. Taking a two-pronged approach, the course includes experimentation with basic ICs such as logic gates and timers as well as with multipurpose ICs such as microcontrollers that can be programmed to mimic the function of many basic ICs. This counts toward the experimental elective for the major. Prerequisite: PHYS 380 (may be taken in the same semester). Offered in alternate years and runs only in the second half of the semester.

Advanced Experimental Physics 1

PHYS 385 CREDITS: 0.25/2 QR

This course is an introduction to upper-level experimental physics that prepares students for work in original research in physics and for work in industry applications of physics. Students acquire skills in experimental design, observation, material preparation and handling, and equipment calibration and operation. Experiments are selected to introduce students to concepts, techniques and equipment useful in understanding physical phenomena across a wide range of physics subdisciplines, with the twofold goal of providing a broad overview of several branches of experimental physics and preparing students to undertake any experiments in PHYS 386 and 387. This course is required as part of the 1 unit of upper-level experimental physics coursework to complete the major in physics. Prerequisite: PHYS 241, 245 and 380. Offered every spring and runs only the first half of the semester.

Advanced Experimental Physics 2

PHYS 386 CREDITS: 0.25/2 QR

In this course, students explore fundamental physical interactions between light and matter, such as Compton scattering, Rayleigh and Mie scattering, and matter-antimatter annihilation, while also learning to use common nuclear and optical detection and analysis techniques. This counts toward the experimental elective for the major. Prerequisite: PHYS 385 (may be taken in the same semester). Offered in alternate years and runs only the second half of the spring semester.

Advanced Experimental Physics 3

PHYS 387 CREDITS: 0.25/2 QR

In this course, students probe the structure of solids using X-ray crystallography and atomic force microscopy, study the physical properties of semiconductors, and use the manipulation of magnetic fields to examine the resonant absorption of energy in atoms and nuclei. This counts toward the experimental elective for the major. Prerequisite: PHYS 385 (may be taken in the same semester). Offered in alternate years and runs only the second half of the spring semester.

Individual Study

PHYS 493 CREDITS: 0.25-0.5/2-4

Individual studies may involve various types of inquiry: reading, problem solving, experimentation, computation, etc. To enroll in individual study, a student must identify a physics faculty member willing to guide the course and work with that professor to develop a description. The description should include topics and content areas, learning goals, prior coursework qualifying the student to pursue the study, resources to be used (e.g., specific texts, instrumentation), a list of assignments and the weight of each in the final grade, and a detailed schedule of meetings and assignments. The student must submit this description to the physics department chair for approval. In the case of a small-group individual study, a single description may be submitted and all students must follow that plan. The amount of work in an individual study should approximate the work typically required in other physics courses of similar types at similar levels, adjusted for the amount of credit to be awarded. Individual study courses should supplement, not replace, courses regularly offered by the department. Because students must enroll for individual studies by the end of the seventh class day of each semester, they should begin discussion of the proposed individual study the semester before, so that there is time to devise the proposal and seek departmental approval. An individual study course in physics is ordinarily designed for 0.25 unit of credit and cannot count towards the QR (quantitative reasoning) requirement unless special arrangements are made with the chair of the department, in consultation with the registrar's office.

Senior Honors

PHYS 497Y CREDITS: 0.5/4

This course offers guided experimental or theoretical research for senior honors candidates. Students enrolled in this course are automatically added to PHYS 498Y for the spring semester. Permission of instructor and department chair required, as is cumulative GPA above the College-mandated minimum.

Senior Honors

PHYS 498Y CREDITS: 0.5/4

This course offers guided experimental or theoretical research for senior honors candidates. Permission of instructor and department chair required, as is cumulative GPA above the College-mandated minimum.

Introduction to Topics in Physics

PHYS 95 CREDITS: 0.25/2

This course will introduce the theory behind concepts covered in the first year of the Kenyon physics curriculum and will enable the performance of experiments in those areas. Topics will include kinematics, dynamics, impulse and momentum, work and energy, electricity, circuits, atomic physics and nuclear physics. The course will be taught using a combination of lectures, labs, in-class exercises, homework assignments and examinations. Seven full (three-hour) labs will be performed along with supporting activities. Lectures cover the theory and instrumentation required to understand each experiment. Students will continue to develop skills in computer-assisted graphical and statistical analysis of data. The final exam will be an in-lab exam similar to those performed during the Kenyon academic year. Knowledge of calculus is not required. Prerequisite: Acceptance into Camp 4. Offered every Camp 4 session.