

# Physics Capstone

PHYS 402 • Fall 2024

Centenary College of Louisiana

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| <b>Instructor</b>   | Dr. David Kordahl   | <b>Email</b>         | <a href="mailto:dkordahl@centenary.edu">dkordahl@centenary.edu</a> |
| <b>Office</b>       | Centenary Square 203B                                       | <b>Class Meeting</b> | MWF 12:00–12:50 pm, Mickle Hall 110                                |
| <b>Office Hours</b> | T 9:35 am–12:00 pm<br>W 9:00–11:00 am<br>F 11:00 am–2:00 pm |                      |  |

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## Course at a Glance

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| <b>Course</b>       | PHYS 402: Physics Capstone   |
| <b>Credits</b>      | 2 credit hours   |
| <b>Prerequisite</b> | PHYS 302: Modern Physics   |
| <b>Texts</b>        | Sean Carroll, <i>The Biggest Ideas in the Universe, Vol. 1: Space, Time, and Motion</i> and <i>Vol. 2: Quanta and Fields</i> ; additional handouts and library resources provided through Canvas |
| <b>Major Work</b>   | Physics review, reading reflections, homework preparation, career exploration paper, resume, and final portfolio   |

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## Course Description

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Physics Capstone is a two-credit seminar designed to help students draw together the physics they have learned across the major and prepare for professional life after college. The course combines broad review of the undergraduate physics curriculum with career preparation, reflective writing, and portfolio development.

Students will revisit major ideas from classical mechanics, relativity, electromagnetism, waves and optics, quantum mechanics, and thermal/statistical physics. This review is intended to strengthen students' "big picture" understanding of physics and to support preparation for standardized assessments such as the Major Field Test in Physics or the Physics GRE.

At the same time, students will develop materials that help them communicate their skills and accomplishments beyond the classroom. Each student will draft a resume, assemble a portfolio of representative work from the physics major, and write an 8–10 page career exploration paper on a professional path related to their interests.

## Learning Goals

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By the end of PHYS 402, students should be able to:

- review and synthesize core undergraduate physics topics, including mechanics, electromagnetism, waves, modern physics, quantum mechanics, and thermal/statistical physics;
- explain connections among major physical theories and identify some of their domains of validity, limitations, and open questions;

- prepare for standardized physics assessments by revisiting foundational concepts and solving representative review problems;
- research a career path available to physics graduates and communicate that research in a polished 8–10 page paper;
- assemble a professional portfolio that represents their work in the physics major, including selected coursework, project materials, and a complete resume;
- reflect on the skills developed through the physics major and describe those skills to audiences outside the discipline.

## Course Structure

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This course has two closely related purposes. First, it provides a structured opportunity to consolidate physics knowledge accumulated throughout the major. The weekly physics review is not meant to replace earlier coursework; instead, it asks students to step back, see how major topics fit together, and practice articulating essential ideas clearly.

Second, the course helps students prepare for life after graduation. Physics majors leave the program with analytical, computational, mathematical, experimental, and communication skills that can be applied in many settings. The career exploration paper, resume, and portfolio are designed to help students identify those skills and present them effectively to graduate programs, employers, and other professional audiences.

## Major Assignments

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### Physics Review and Homework Preparation

Each week includes readings and review exercises connected to the major physics topic under discussion. Students are expected to come to class prepared to discuss the reading, ask questions, and work through review problems collaboratively.

### Reading Reflections

Students will submit brief Canvas reflections before selected class meetings. These reflections are intended to prepare students for discussion and to encourage regular engagement with the readings. They need not be long, but they should show thoughtful preparation.

### Career Exploration Paper

Each student will research a career path relevant to their interests and write a polished 8–10 page paper. The paper should describe the nature of the work, the preparation required, the relevance of physics training, and the student's own reflections on whether and how this path fits their goals.

### Portfolio

Each student will assemble a portfolio representing their work as a physics major. The portfolio should include work from this course as well as selected work from other courses or projects completed at Centenary. The final portfolio must include a complete resume and samples of the student's

strongest or most representative work. During the final exam period, students will share their resume and discuss what they learned from the career exploration and portfolio process.

## Assessment

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This course is based heavily on preparation, participation, and sustained work on the career exploration and portfolio projects. Because it is a capstone seminar, regular attendance and thoughtful contribution to discussion are central parts of the course.

| Assessment                   |     | Letter Grades |           |
|------------------------------|-----|---------------|-----------|
| Attendance and participation | 20% | A             | 90–100%   |
| Homework preparation         | 20% | B             | 80–89%    |
| Reading reflections          | 20% | C             | 70–79%    |
| Career exploration paper     | 20% | D             | 60–69%    |
| Portfolio                    | 20% | F             | below 60% |

## Minimum Expectations for Graduating Physics Majors

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The capstone review is guided by the following minimum expectations. These statements are not meant to exhaust the physics major, but they identify central ideas and skills that graduating students should be able to discuss and use.

### Mechanics

Students should be able to:

- state Newton's three laws of motion;
- solve projectile motion problems from given initial conditions;
- solve problems involving conservation of energy and momentum;
- solve harmonic oscillator problems in Newtonian, Lagrangian, and Hamiltonian forms;
- describe resonance and damping in the driven damped harmonic oscillator;
- solve problems involving Newton's law of universal gravitation;
- solve problems involving circular motion, including gravitational orbits;
- explain the relationships between work and energy and between impulse and momentum.

### Electromagnetism and Waves

Students should be able to:

- state Gauss's law, Ampere's law, Faraday's law, and the Lorentz force equation;
- solve problems involving Coulomb's law and electric fields from systems of point charges;
- find equivalent circuits for resistors and capacitors in series and parallel;

- solve problems involving electromagnetic induction and changing magnetic flux;
- describe the time-dependent behavior of RC, RL, and RLC circuits;
- describe the role of the displacement current in unifying electromagnetism and optics;
- solve simple problems involving refraction, diffraction, and geometric optics;
- use sinusoidal descriptions of waves, including amplitude, frequency, wavevector, phase, and phase velocity.

### Modern and Quantum Physics

Students should be able to:

- solve problems involving length contraction and time dilation;
- state the foundational postulates of special relativity and describe Lorentz transformations;
- solve problems involving the Doppler effect, including redshift and blueshift of spectra;
- solve problems involving the photoelectric effect;
- solve problems involving de Broglie wavelength and the Heisenberg uncertainty principle;
- describe the role of the Schrödinger equation in making quantum-mechanical predictions;
- solve problems involving the infinite square well in one, two, and three dimensions;
- describe the role of the quantum numbers  $n$ ,  $\ell$ ,  $m_\ell$ , and  $m_s$  in hydrogenic states, including the energy relation  $E_n = -13.6 \text{ eV}/n^2$  and the qualitative meaning of orbital shape.

### Thermal and Statistical Physics

Students should be able to:

- state the zeroth, first, second, and third laws of thermodynamics;
- define temperature in practical and theoretical terms, and distinguish heat, work, and internal energy;
- apply the equipartition theorem to estimate average energy per degree of freedom;
- describe the operation and efficiency of ideal heat engines, including the Carnot cycle;
- define entropy macroscopically and statistically, including  $S = k_B \ln \Omega$ , and discuss its significance;
- calculate multiplicities of simple systems, such as coin flips and Einstein solids;
- apply the Boltzmann factor to compute probabilities and average energies;
- distinguish when Maxwell-Boltzmann, Fermi-Dirac, or Bose-Einstein statistics are appropriate.

## Detailed Course Schedule

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This schedule records the intended sequence of physics review topics and major capstone deadlines. The pacing may be adjusted as needed, but the table reflects the structure of the course.

| Week(s)     | Physics Review  | Capstone Work and Deadlines  |
|-------------|---|--|
| Weeks 1–3   | <b>Classical Mechanics Review.</b> Newton’s laws; particle collisions; conservation laws; energy and momentum; harmonic motion.   | Begin capstone orientation; discuss professional pathways for physics graduates; begin collecting portfolio materials.   |
| Week 4      | <b>Relativity Review.</b> Special relativity; conservation of mass-energy; relativistic kinematics and conceptual foundations.  | <b>September 19:</b> Career exploration brief proposal due.  |
| Weeks 5–9   | <b>Electromagnetism Review.</b> Electrostatics; Coulomb’s law; electric fields and forces; DC circuits; capacitors, resistors, and Kirchhoff’s laws; electromotive force and induction; magnetic fields and forces; inductors and LRC circuits. | Continue career research; discuss how physics skills transfer to technical and nontechnical careers.<br><b>October 24:</b> Career exploration paper rough draft due. |
| Weeks 10–12 | <b>Wave Behavior.</b> Geometric optics and polarization; diffraction and refraction; sinusoidal waves and wave descriptions.  | Revise career exploration paper; connect communication of technical ideas to professional writing.<br><b>November 7:</b> Career exploration paper final draft due.   |
| Weeks 13–14 | <b>Quantum Mechanics.</b> Blackbody radiation; de Broglie waves; the Bohr model; wavefunctions and probability.   | Prepare resume and portfolio materials.<br><b>November 20:</b> Resume due.   |
| Week 15     | <b>Mechanics Redux.</b> Lagrangians, Hamiltonians, and Schrödinger’s equation; unifying views of mechanics and quantum theory.  | Complete final portfolio and prepare final discussion.<br><b>December 12:</b> Final portfolio submission due.  |

## Course Policies

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### Academic Honesty and the Honor Code

All students at Centenary are bound by the Honor Code. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation. It is not considered cheating in this course to share suggestions on assignments with peers, although the final work must ultimately be one's own. Reflection questions can be discussed, but final versions are expected to be completed by students on their own.

Internet resources, including AI tools, are acceptable to use as aids, but only as help along the way. If such resources are consulted, students are required to document how they were used. Copying the work of others, whether AI or human, is prohibited.

Students are required to write the following pledge at the end of any examination or assignment:

*I have neither given nor received unauthorized aid on this examination (paper), nor have I seen anyone else do so.*

If any student has received aid or suspects others of violating the Honor Code, the following clause is to be added to the pledge: "...except as I shall report immediately to the Honor Court." The complete pledge must be written and signed by the student, shall not be abbreviated, and should never be written until the test or paper has been completed for submission. Students are bound by the Honor Code even if they fail to write the pledge on their assignment or examination.

### Attendance

Attendance is required. However, students are expected not to jeopardize their own health or anyone else's health to attend class. Illness-related absences will be excused. There is no penalty for missing class if students proactively communicate with the professor and complete all required work. If a qualified professional deems remaining in classes and fulfilling the necessary requirements impossible, alternatives will be sought in coordination with Student Support Services.

Because this is a two-credit seminar course, sustained participation is essential. More than nine unexcused absences will lead to a failing grade in the course.

### Disability Accommodations

It is the policy of Centenary College to accommodate students with disabilities, pursuant to federal law, state law, and the College's commitment to equal educational opportunities. Any student with a disability who needs accommodations should inform the instructor at the beginning of the course. Students with disabilities need to contact Disability Services, a division of the Center for Teaching and Learning, located in the Learning Commons on the second floor of Magale Library. Disability Services can be reached by telephone at 318-869-5738.

### Diversity Statement

Centenary College of Louisiana values human diversity in all its richly complex and multi-faceted forms, whether expressed through race and ethnicity, culture, political and social views, religious and spiritual beliefs, language and geographic characteristics, gender, gender identities and sexual orientations, learning and physical abilities, age, and social or economic classes.