# PHYS 221: Modern Physics & Quantum Phenomena

**Term:** Fall 2026
**Credits:** 4.0
**Lecture Times & Location:** Monday, Tuesday, Wednesday, Friday 10:00–10:50 a.m., Meridian Science Center 140
**Modality:** In-Person



## Instructor Information

- **Instructor:** Dr. Chidi Okoro (Associate Professor of Physics)
- **Email:** cokoro@university.alkimi.ai
- **Office:** Meridian Science Center 412
- **Office Hours:**
  - Monday & Thursday: 1:00–2:30 p.m. (In person, Meridian Science Center 412)
  - Wednesday: 2:00–3:00 p.m. (Virtual via Zoom; link posted in Canvas)
  - Also available by appointment.

## Course Description

Special relativity, the photoelectric effect, wave-particle duality, the Bohr atom, the Schrödinger equation in one dimension, atomic structure, nuclear physics, and an introduction to particle physics. PHYS 221 bridges classical physics and the modern quantum and relativistic paradigm, establishing the theoretical framework for advanced studies in physical science. We explore Einstein's special theory of relativity, the experimental failures of classical mechanics, early quantum models, and wave-particle duality. The central portion of the semester is devoted to solving the time-independent Schrödinger equation in one dimension for bound and scattering states, followed by extensions to the hydrogen atom, atomic spectroscopy, nuclear stability, and elementary particle classifications.

### Prerequisites

PHYS 122 and MATH 141.

## Measurable Student Learning Outcomes

Upon successful completion of PHYS 221, students will be able to:

1. **Apply Special Relativity:** Calculate time dilation, length contraction, relativistic velocity additions, relativistic energy, and relativistic momentum in inertial reference frames.
2. **Analyze Quantum Phenomena and Wave-Particle Duality:** Explain key historical experiments including blackbody radiation, the photoelectric effect, Compton scattering, and electron diffraction.
3. **Solve the One-Dimensional Schrödinger Equation:** Formulate boundary conditions and solve the time-independent Schrödinger equation for infinite and finite square wells, potential barriers (tunneling), and the harmonic oscillator.

4. **Examine Three-Dimensional Quantum Systems and the Hydrogen Atom:** Characterize quantum numbers (principal, orbital, magnetic, spin), electron orbital shapes, and energy spectra in hydrogenic atoms.
5. **Evaluate Multi-Electron Atoms and the Periodic Table:** Apply the Pauli exclusion principle, Hund's rules, and angular momentum coupling to atomic electron configurations and fine structure.
6. **Investigate Nuclear and Particle Physics Fundamentals:** Calculate nuclear binding energies, decay rates, and Q-values, and classify elementary particles and conservation laws in the Standard Model.

## Required Course Materials & Approximate Costs

1. **Thornton, Stephen T., and Andrew Rex. *Modern Physics for Scientists and Engineers*. 5th ed., Cengage Learning, 2020.** Approx. $55 for digital rental; approx. $135 for print purchase.
2. **Scientific calculator with scientific and exponential functions.** Approx. $15 to $25.
3. **Total estimated cost:** $15 to $160.

## Generative AI Policy (AI Level 2: AI Permitted with Disclosure for Specified Tasks)

In accordance with Alkimi University Academic Policies (Student Handbook §5.8), PHYS 221 operates under **AI Level 2**.

- **What is permitted:** You may use AI tools to visualize Lorentz transformations, explore numerical solutions to the one-dimensional Schrödinger equation, clarify physical interpretations of quantum paradoxes, and generate extra conceptual practice problems.
- **What is prohibited:** You may not submit AI-generated derivations or problem solutions as your own work, use AI to complete computational homework assignments without attribution, or access any AI or network tools during midterm or final examinations.
- **Disclosure:** For each written problem set, include a statement identifying any AI tools consulted and detailing how you verified the mathematical derivations, or declare that no AI tools were used.

## Grading Components and Weights

- **Midterm Exam 1:** 20% (In class, Friday, September 25)
- **Midterm Exam 2:** 20% (In class, Friday, October 30)
- **Weekly Problem Sets:** 25% (Due Fridays at 11:59 p.m. in Canvas (weeks 2–13; lowest dropped))
- **Computational Physics Exercises:** 10% (Biweekly numerical modeling assignments due Wednesdays at 11:59 p.m. in Canvas)
- **Final Comprehensive Examination:** 25% (Monday, December 14, 2026, 10:00 a.m.–12:00 p.m.)

### Grading Scale (Alkimi University Standard)

- **A:** 93–100% | **A-:** 90–92%
- **B+:** 87–89% | **B:** 83–86% | **B-:** 80–82%
- **C+:** 77–79% | **C:** 73–76% | **C-:** 70–72%
- **D+:** 67–69% | **D:** 60–66% | **F:** Below 60%
- **Extra credit:** No extra credit assignments are offered in PHYS 221.

## Course Schedule (Fall 2026)

| Week | Dates | Topics & Readings | Assignments & Deadlines |
|---|---|---|---|
| **Week 1** | Aug 26, 28 | **Foundations of Relativity and Michelson-Morley:** Galilean transformations, luminiferous aether hypothesis, Michelson-Morley interferometer experiment, and the null result. *Reading: Thornton Ch. 1 & 2.1–2.2* | *First day of classes: Wed Aug 26.* |

| Week | Dates | Topics & Readings | Assignments & Deadlines |
|---|---|---|---|
| **Week 2** | Aug 31–Sep 4 | **Special Relativity: Kinematics and Spacetime:** Einstein's postulates, relativity of simultaneity, time dilation, length contraction, Lorentz transformations, and Minkowski diagrams. *Reading: Thornton Ch. 2.3–2.6* | *Wed Sep 2: Add/section change deadline.* |
| **Week 3** | Sep 8–11 | **Relativistic Mechanics: Momentum and Energy:** Relativistic momentum, relativistic kinetic energy, mass-energy equivalence (E=mc^2), four-vectors, and relativistic collisions. *Reading: Thornton Ch. 2.7–2.12* | *Mon Sep 7: Labor Day (no classes). Wed Sep 9: Census date (last day to drop without a W).* |
| **Week 4** | Sep 14–18 | **Origins of Quantum Theory: Radiation and Quanta:** Blackbody radiation spectrum, Rayleigh-Jeans law, Wien's displacement, Planck's quantum hypothesis, and cavity radiation. *Reading: Thornton Ch. 3.1–3.3* | — |
| **Week 5** | Sep 21–25 | **Photons and Matter Interactions & Midterm Exam 1:** Photoelectric effect, stopping potential, work function, Compton scattering derivation, and pair production; Midterm Exam 1 in class. *Reading: Thornton Ch. 3.4–3.8* | **Midterm Exam 1 (in class).** |
| **Week 6** | Sep 28–Oct 2 | **Atomic Structure and the Bohr Model:** Thomson model, Rutherford alpha scattering, emission spectra, Bohr postulates for hydrogen, Rydberg formula, and Franck-Hertz experiment. *Reading: Thornton Ch. 4* | — |
| **Week 7** | Oct 5–9 | **Wave-Particle Duality and Matter Waves:** De Broglie hypothesis, matter wavelength, Davisson-Germer electron diffraction experiment, and electron microscopy principles. *Reading: Thornton Ch. 5.1–5.4* | — |
| **Week 8** | Oct 14, 16 | **Uncertainty Principle and Wave Packets:** Heisenberg uncertainty relations for position-momentum and energy-time, wave packets, phase and group velocity, and probability waves. *Reading: Thornton Ch. 5.5–5.8* | *Oct 12–Oct 13: Fall break (no classes). Fri Oct 16: Midterm grades due.* |
| **Week 9** | Oct 19–23 | **The Schrödinger Wave Equation in One Dimension:** Time-dependent and time-independent Schrödinger equations, Born statistical interpretation of wave functions, normalization, and expectation values. *Reading: Thornton Ch. 6.1–6.3* | — |
| **Week 10** | Oct 26–30 | **Bound State Problems & Midterm Exam 2:** Infinite square well (particle in a box), energy eigenvalues, stationary states, and the finite potential well; Midterm Exam 2 in class. *Reading: Thornton Ch. 6.4–6.6* | **Midterm Exam 2 (in class).** |
| **Week 11** | Nov 2–6 | **Quantum Tunneling and the Harmonic Oscillator:** Potential step, rectangular barrier penetration, transmission coefficients, alpha decay tunneling, and quantum harmonic oscillator states. *Reading: Thornton Ch. 6.7–6.9* | *Fri Nov 6: Last day to withdraw (W) or elect Pass/No Pass.* |
| **Week 12** | Nov 9–13 | **Quantum Mechanics in Three Dimensions: Hydrogen:** Schrödinger equation in spherical coordinates, separation of variables, radial wave functions, spherical harmonics, and orbital quantum numbers. *Reading: Thornton Ch. 7* | — |
| **Week 13** | Nov 16–20 | **Angular Momentum and Spin:** Orbital angular momentum operators, Stern-Gerlach experiment, electron intrinsic spin, spin-orbit coupling, and fine structure. *Reading: Thornton Ch. 8* | — |
| **Week 14** | Nov 23, 24 | **Atomic Physics and the Periodic Table:** Identical particles, symmetric and antisymmetric states, Pauli exclusion principle, Hund's rules, and multi-electron atom configurations. *Reading: Thornton Ch. 9* | *Nov 25–Nov 27: Thanksgiving break (no classes).* |
| **Week 15** | Nov 30–Dec 4 | **Nuclear Structure and Radioactivity:** Nuclear radius, binding energy curve, liquid drop model, radioactive decay law, alpha, beta, and gamma radiation, and nuclear reactions. *Reading: Thornton Ch. 12 & 13* | — |

| Week | Dates | Topics & Readings | Assignments & Deadlines |
|---|---|---|---|
| **Week 16** | Dec 7–9 | **Particle Physics and Semester Synthesis:** Fundamental forces, leptons, quarks, hadrons, conservation laws, standard model overview, and final exam synthesis. *Reading: Thornton Ch. 14 & Review* | *Wed Dec 9: Last day of classes. Thu Dec 10: Reading Day.* |
| **Finals** | Dec 14 | **Final Comprehensive Examination:** Monday, December 14, 2026, 10:00 a.m.–12:00 p.m., Meridian Science Center 140. | Comprehensive examination covering special relativity, quantum mechanics in 1D and 3D, and nuclear physics. |

## Course Policies

### Attendance Policy

Regular attendance at all four weekly lecture meetings is required. Modern physics introduces abstract mathematical and philosophical concepts best developed through real-time dialogue and problem derivation. If you are absent due to illness or approved university business, notify Dr. Okoro via email in advance. More than four unexcused absences may reduce your course grade. Students who miss the first two class meetings without notifying the instructor may be dropped. Students may miss class for religious observance without penalty if they notify the instructor in writing within the first two weeks of the semester (by Wednesday, September 9, 2026). Absences for university-sponsored activities (athletics, performances, conferences) are excused with a letter from the sponsoring office at least one week in advance.

### Late Work Policy

Problem sets submitted up to 24 hours late receive an automatic 20% point reduction. Problem sets submitted more than 24 hours past the deadline will not be evaluated as complete solutions are posted immediately. To account for emergencies, the lowest weekly problem set score is dropped.

### Final Exam Policy

The final examination (Monday, December 14, 2026, 10:00 a.m.–12:00 p.m.) is scheduled by the University Registrar and can't be moved without the Dean's written approval (Faculty Handbook §5.5). A student with three or more final exams on the same calendar day may reschedule one of them. Requests go to the instructor of the middle exam by the last day of classes. For this term, send the request by Wednesday, December 9, 2026 (Student Handbook §6.4).

## Academic Integrity

Alkimi University is an academic community devoted to rigorous scholarship, open intellectual inquiry, and uncompromising ethical conduct. All students are subject to the regulations of the Alkimi University Academic Integrity Policy. Academic dishonesty—including plagiarism, cheating on examinations, unauthorized collaboration, fabrication of empirical data, and unauthorized submission of academic work generated by artificial intelligence—undermines the integrity of the university and carries severe disciplinary sanctions. Sanctions range from a failing grade on an assignment or exam to an administrative course failure recorded as an 'XF' on the official transcript, academic suspension, or expulsion. Suspected violations are formally investigated and resolved through the Office of Academic Integrity in accordance with Faculty Handbook §6. For detailed information, consult the Office of Academic Integrity, Lovell Hall 315, (555) 555-0163, integrity@university.alkimi.ai.

## Accessibility Services

Alkimi University is committed to providing equitable educational access and reasonable accommodations for all students with documented disabilities, including physical, sensory, psychological, learning, and chronic health conditions. Students requesting academic accommodations must formally register with the Office of Accessibility Services, Harlan Hall 204, (555) 555-0155, access@university.alkimi.ai. Once approved,

students will receive an official Faculty Accommodation Letter detailing approved accommodations. Students should present this letter to the instructor as early in the semester as possible, and at least one week prior to any exam or assignment requiring accommodation. Accommodations cannot be applied retroactively.

## Student Wellness and Mental Health

Your physical health, psychological well-being, and mental health are essential to your academic success. If you experience heightened stress, anxiety, depressive symptoms, personal trauma, or academic burnout, free, confidential counseling and medical care are available through the Hollis Health & Counseling Center, located in the Hollis Center. Routine appointments are available Monday–Friday 8:00 a.m.–6:00 p.m. and Saturday 10:00 a.m.–2:00 p.m. during the semester by calling (555) 555-0190 or emailing health@university.alkimi.ai. Urgent, 24/7 crisis psychological counseling is accessible immediately at (555) 555-0199.

## Campus Student Support Services

- **Academic Advising Center:** Lovell Hall 101 | (555) 555-0158 | advising@university.alkimi.ai
- **Writing Center:** Whitcombe Library 3rd Floor | Free consultations on papers, reports, and research projects at any stage.
- **Whitcombe Library:** Whitcombe Library, Main Floor | (555) 555-0170 | askalibrarian@university.alkimi.ai
- **Hollis Health & Counseling Center:** Hollis Center | (555) 555-0190 | 24/7 Counseling Line: (555) 555-0199 | health@university.alkimi.ai
- **Physics Tutoring Center:** Drop-in peer tutoring and conceptual assistance are available Monday through Thursday from 2:00 to 6:00 p.m.