Modern Physics

PHYS 3710 – Fall 2022

Instructor Info

Dr. Andreas Papaefstathiou

Office Hrs: By appointment

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Course Info

Prereq: Grade "C" or higher in PHYS 2212 and PHYS 2212L

Mon & Wed

3:30-4:45 p.m.

Academic Building 322 (Marietta Campus)

Course Overview

The topics covered in this course constitute the two fundamental pillars of Modern Physics: relativity and quantum physics. The main objective of this course is to provide a basic understanding of the physical laws and phenomena that constitute the framework leading to special relativity and quantum mechanics. In particular, students will strengthen their knowledge of special relativity and explore aspects of the quantum theory of wave/particle duality and its probabilistic interpretation. The Schrödinger equation will be examined in detail, along with its solutions for simple potentials. The properties of the one-electron atom will be described. Students will also study applications of quantum principles to atomic, molecular and nuclear structures.

Learning Objectives

At the completion of this course, students will be able to

- Use special relativity with four-vectors to analyze differences in the behavior of objects as observed in different inertial reference frames and explain the equivalence of mass and energy.
- Describe the major aspects of the most important experiments that have led to the development of quantum theory.
- Explain the Rutherford model of the nucleus and the Bohr model of the atom.
- Discuss wave-particle duality and Heisenberg's uncertainty principle.
- Use Schrödinger's equation to solve various simple systems.
- Discuss the spin of the electron orbital and shells for atoms, quantum numbers, and Pauli's exclusion principle.

Required Text and Material

Main Textbook: J. R. Taylor, C. D. Zafiratos and M. A. Dubson, *Modern Physics for Scientists and Engineers*, 2nd Edition.

Auxiliary Textbooks (you do not have to buy these):
P. Tipler and R. Llewellyn, *Modern Physics*.
J. R. Forshaw and A. G. Smith, *Dynamics and Relativity*.
D. Tong, *Electromagnetism and Relativity* (https://www.damtp.cam.ac.uk/user/tong/em/el4.pdf).
D. J. Griffiths and D. F. Schroeter, *Introduction to Quantum Mechanics*.
D. V. Schroeder, *Notes on Quantum Mechanics*. (https://physics.weber.edu/schroeder/quantum/QuantumBook.pdf)

D2L

Course information, homework solutions and announcements will be available on D2L, accessible from https://d2l.kennesaw.edu. To sign on, use your KSU username and password. You are expected to check D2L for announcements at least once a day.

Homework Assignments

Homework will be assigned during the lectures and posted on D2L. Solutions to problems will be discussed in class and will also be posted on D2L.

Please only ask for extensions if you have a valid emergency reason. Make an attempt to look at the problems sufficiently in advance and if you have any questions contact me well in advance so they can be resolved. If you believe you do have a valid reason, contact me via e-mail.

Reading Assignments

You are expected to read the textbook before the lecture. Class time will be used for discussion and problem solving. The sections of the text we will be covering are on the syllabus.

Communication

Only use e-mail to contact me (i.e. not D2L) at apapaefs@kennesaw.edu. Make sure that the subject line starts with "PHYS3710". You must use your KSU e-mail address.

I will return all emails in 36-hours during the week and within 48 hours over the weekends.

Evaluation and Grading Policies

15%	Homework
60%	Three Tests, 20% each
25%	Final Exam

Grades will follow the scale: A = 89.5-100; B = 79.5-89.4; C = 69.5-79.4; D = 60-69.4; F $<$60. Curving is at the discretion of the instructor.

The lowest homework assignment will be dropped. There will be extra credit in the assigned homework in the form of bonus questions. The bonus marks will be summed up throughout all the homework assignments, and the achieved fraction will contribute up to 5% extra credit, in addition to the percentage achieved through Homework, Tests and the Final Exam.

Tests and exams are graded by assigning points for:

- Correctly identifying the physics of the problem.
- Setting up correctly all the equations (and/or graphs/diagrams) for the specific physics situation described in the problem and commenting when necessary or relevant.
- Correctly identifying all unknown physical variables/observables to be determined.
- Correctly working out all the symbolic and differential calculus-based operations.
- Correctly working out all the algebraic calculations to determine the solution.

Exams and Make-up Policy

Four tests will be given this semester: three tests and a final exam. The test dates are on the attached course schedule. The final exam will be comprehensive. Each test will be a combination of multiple-choice questions, conceptual questions and problem-solving, free response questions.

Make-up exams or tests will not be given. If you know ahead of time you have a conflict, let me know. If you miss an exam because of an illness (yours or a family member's) or some other unforeseeable event, contact me as soon as you can. You can e-mail me, leave a message on my answering machine or call the Physics Department office at 470-578-4205. You must provide documentation showing the reason for missing the exam, if asked.

Course Dos and Don'ts

Please review these important points that will help you throughout the rest of your college career, and in your future careers.

- Regular attendance is essential for success in this class. If students miss a class, it is their responsibility to get the notes for missed lectures from another student. And please be on time!
- Occasionally, it may be necessary for the instructor to make corrections, updates or changes to this syllabus. Corrections or changes to the syllabus will be announced on D2L and in class: students are expected to check D2L for announcements regularly (i.e. at least once or twice a day.)
- Cellular telephones, pagers, and similar devices must be turned off or placed in silent mode during lectures. Use of cell phones should be restricted to emergencies.
- In class, avoid conversations and other disruptions that may distract other students during the lecture. If you have questions or comments, direct it to the instructor.
- Rude and disrespectful student behavior will not be tolerated (administrative actions will be taken).
- Deadlines are deadlines for a reason. As a college student, you must plan accordingly and use your time wisely. In the "real world" you are expected to submit work on time to your boss so that you keep your job. I expect the same.
- If you have asked your professor to grant you an extension on your work, you do not meet the guidelines for getting an extension, and are told "no," do not continue to email the professor. No means no, and this is grounds for a referral to student conduct.

- Do not tell your professors or employers how to do their jobs. While you may not like your professor or employer, remember that they have more experience in and knowledge about the field than you. They are also your means for networking and finding gainful employment.
- Remember that your professional aptitude not only reflects on you as a student and employee, but as a person in general. Please be sure you understand these guidelines, and if you have any questions about appropriate communication or college-level problem-solving skills, let me know.

Course Delivery

KSU may shift the method of course delivery at any time during the semester in compliance with University System of Georgia health and safety guidelines. In this case, alternate teaching modalities that may be adopted include hyflex, hybrid, synchronous online, or asynchronous online instruction.

Face Coverings

Based on guidance from the University System of Georgia (USG), masks are encouraged based on individual preference and assessment of personal risk. Disposable face coverings can be picked up at the Office of Emergency Management at Chastain Pointe on the Kennesaw campus and Norton Hall Police Precinct on the Marietta campus. Please email oem@kennesaw.edu if you have questions.

Academic Integrity

Every KSU student is responsible for upholding the provisions of the Student Code of Conduct, as published in the Undergraduate and Graduate Catalogs. Section 5c of the Student Code of Conduct addresses the university's policy on academic honesty, including provisions regarding plagiarism and cheating, unauthorized access to university materials, misrepresentation/falsification of university records or academic work, malicious removal, retention, or destruction of library materials, malicious/intentional misuse of computer facilities and/or services, and misuse of student identification cards. Incidents of alleged academic misconduct will be handled through the established procedures of the Department of Student Conduct and Academic Integrity (SCAI), which includes either an "informal" resolution by a faculty member, resulting in a grade adjustment, or a formal hearing procedure, which may subject a student to the Code of Conduct's minimum one semester suspension requirement.

All students are responsible for knowing the information, policies and procedures outlined in the Kennesaw State University Codes of Conduct. The Code is available online at `http://scai.kennesaw.edu/`.

Accommodations for Students with Disabilities

Any student with a documented disability or medical condition needing academic accommodations of class-related activities or schedules must contact the instructor as early in the semester as possible. This applies to accommodations for medical conditions related to COVID-19. Written verification from the KSU Student Disability Services (`https://sds.kennesaw.edu/`) is required. No requirements exist that accommodations be made prior to completion of this approved University documentation. All discussions will remain confidential.

Withdrawal Policy

Students are solely responsible for managing their enrollment status in a class.

Non-attendance does not constitute a withdrawal.

The last day to withdraw without academic penalty is Tuesday, October 11th 2022, 11:45 p.m.

Additional information on the withdrawal policy can be found at: `http://catalog.kennesaw.edu/content.php?catoid=51&navoid=3701#withdrawalfromclasses`.

The Academic Standing Appeal policy is explained at: `https://appeals.kennesaw.edu/withdrawal_appeal.php`.

Campus Sexual Misconduct Policy

For information about how to report sexual misconduct or how to obtain assistance, please go the following page: `https://scai.kennesaw.edu/procedures/sexual-misconduct.php`.

Other Policies

See the Student Handbook (http://catalog.kennesaw.edu/) for other policies and information.

KSU SMART Center

If you require tutoring assistance, the Science and Math Academic Resource and Tutoring (SMART) Center at KSU provides tutoring for all current KSU students in Math, Science, Engineering, Humanities, and Social Science courses. See https://academicaffairs.kennesaw.edu/smart/index.php for further details.

COVID-19 illness

If you are feeling ill, please stay home and contact your health professional. In addition, please email your instructor to say you are missing class due to illness. Signs of COVID-19 illness include, but are not limited to, the following:

- Cough
- Fever of 100.4 F or higher
- Runny nose or new sinus congestion
- Shortness of breath or difficulty breathing
- Chills
- Sore Throat
- New loss of taste and/or smell

COVID-19 vaccines are a critical tool in "Protecting the Nest." If you have not already, you are strongly encouraged to get vaccinated immediately to advance the health and safety of our campus community. As an enrolled KSU student, you are eligible to receive the vaccine on campus. Please call (470) 578-6644 to schedule your vaccination appointment.

For more information regarding COVID-19 (including testing, vaccines, extended illness procedures and accommodations), see KSU's official Covid-19 website, https://www.kennesaw.edu/coronavirus/.

Class Schedule (Tentative)

PART I: The Theory of Special Relativity

Week 1	Aug 15	*Chapter 1: A New Theory of Space and Time.* Introduction to Relativity. The speed of light. The Michelson-Morley experiment. Einstein's postulates.
	Aug 17	Time dilation, length contraction and simultaneity, The Lorentz transformations. The velocity-addition formula.
Week 2	Aug 22	*Chapter 2: Relativistic Mechanics.* Mass in Relativity. Relativistic Momentum. Relativistic Energy. Useful relations in Relativity. Conversion of mass to energy.
	Aug 24	Force in Relativity. Massless particles. When is Non-relativistic mechanics good enough?
Week 3	Aug 29	*Chapter 3: The Symmetries of Space and Time.* Symmetries in Physics. Rotations and Translations. Galilean symmetry.
	Aug 31	Lorentz Symmetry. four-vectors and Lorentz invariants. The wave four-vector. The energy-momentum four-vector. Space-time diagrams. Relativity and causality.
Week 4	Sep 5	BREAK
	Sep 7	*Chapter 4: Electromagnetism and Relativity.* Four-vectors revisited. Raising and lowering indices. Vectors, covectors and tensors. Conserved currents.
Week 5	Sep 12	Magnetism and Relativity. Gauge potentials and gauge transformations. The electromagnetic tensor.
	Sep 14	Boosted point charge. Lorentz scalars in electromagnetism. Maxwell's equations in four-vector form. The Lorentz force law.
Week 6	Sep 19	TEST 1

PART II: An Introduction to Quantum Mechanics

	Sep 21	*Chapter 5: Atoms.* Elements, atoms and molecules. Electrons, protons and neutrons. Atomic parameters. The atomic mass unit. Avogadro's number and the mole. Kinetic theory of ideal gases. Diffusion and random walk motion. Brownian motion.
Week 7	Sep 26	Thomson's and Millikan's experiments. Rutherford's model of the nuclear atom.
	Sep 28	*Chapter 6: Quantization of Light.* Blackbody radiation and Planck's theory. The photoelectric effect. X-rays and Bragg diffraction. The Compton effect. Wave-particle duality.
Week 8	Oct 3	*Chapter 7: Quantization of Atomic Energy Levels.* Atomic spectra. The Balmer-Rydberg Formula. The problem of atomic stability. Bohr's explanation of the atomic spectra. The Bohr model of the Hydrogen atom.

	Oct 5	Properties of the Bohr atom. Hydrogen-like ions. X-ray spectra.
Week 9	Oct 10	*Chapter 8: Matter Waves.* The De Broglie Hypothesis. The Quantum Wave Function. Sinusoidal waves.
	Oct 12	Wave packets and Fourier analysis. The Heisenberg uncertainty principle.
Week 10	Oct 17	*Chapter 9: The Schrödinger Equation in one Dimension.* Classical standing waves. Standing waves in Quantum Mechanics and stationary states. Particle in a rigid box.
	Oct 19	The time-independent Schrödinger equation. The rigid box again. The non-rigid box. The simple harmonic oscillator. Tunneling. The time-dependent Schrödinger equation.
Week 11	Oct 24	TEST 2
	Oct 26	*Chapter 10: The Three-Dimensional Schrödinger Equation.* Partial derivatives. The two-dimensional square box. The two-dimensional central force problem.
Week 12	Oct 31	The three-dimensional central-force problem.
	Nov 2	Hydrogenic wave functions. Hydrogen-like ions.
Week 13	Nov 7	*Chapter 11: Electron Spin.* Spin angular momentum. Magnetic moments. The Zeeman effect.
	Nov 9	TEST 3
Week 14	Nov 14	Spin magnetic Moments. The anomalous Zeeman effect. Fine structure.
	Nov 16	*Chapter 12: Multielectron Atoms and the Pauli Exclusion Principle.* The independent-particle approximation.
Week 15	Nov 21	BREAK
	Nov 23	BREAK
Week 16	Nov 28	The Pauli exclusion principle. Fermions and Bosons.
	Nov 30	Ground states of the first few elements. The periodic table.
Week 17	Dec 5	LAST DAY OF CLASSES - REVISION
	Dec 7	NO CLASS
Week 17	Dec 12	FINAL EXAM