Modern Physics

PHY 321
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SC-P132 PH: 771-3162
Office Hours:

Course Description: Fundamental concepts of modern physics are covered, including topics in the special theory of relativity, wave-particle duality, quantization of energy, Schrödinger equation, potential wells, and atomic physics. Experimental basis for modern physics is discussed. Problems at the end of each chapter are excellent preparations for examinations. Sample problems will be worked out during the class. Laboratory exercises are an integral part of the course.

Course Materials

Text: R. A. Serway, C. J. Moses, and C. A. Moyer, "Modern Physics," 3rd Edition, Brooks/Cole Cengage Learning (2005).
Laboratory Instructions: posted on Canvas

Course Requirements

Class attendance, completion of electronic homework associated with each chapter, completion of lab activities and a formal lab report, two tests, and a final exam.

Course Goals:

1. To present the emergence of the "new physics" in the twentieth century by following the thought processes that led to the developments of modern physics theories.

   Learning Goals:

   1.1 Develop an understanding of the physical properties of entities at speeds that approach the speed of light in vacuum.
   1.2 Apply modern physics theories to the microscopic universe.
   1.3 Develop an appreciation of the historical context and evolution of modern physics.
   1.4 Apply the wave-particle duality to waves and particles.

2. To present the experimental basis for modern physics.

   Learning Goals:

   2.1 Replicate many of the experiments that predicted or verified the basis of modern physics.
   2.2 Become proficient in using instrumentation such as oscilloscopes, digital multimeters, power supplies, lasers, photodetectors, interfaces, and spectrometers.
   2.3 Gain experience utilizing simulation programs that demonstrate principles not easily reproducible in an undergraduate lab.

3. To provide a foundation in physics necessary for further study in science, engineering and technology.

   Learning Goals:

   3.1. Apply understanding of energy and momentum to microscopic systems and objects moving at relativistic speeds.
   3.2. Develop an understanding of space-time coordinate systems.
   3.3. Develop an understanding of the wave-particle duality of light and matter and its impact on properties of physical systems.
   3.4. Develop an understanding of the semi-classical atomic model, its applications, and limitations.
   3.5. Develop an understanding of Schrodinger's equation and its application to single electron systems, tunneling, scattering, and various potential barriers.

4. To contribute to the students' essential knowledge base and critical thinking skills necessary for solutions of practical problems.

   Learning Goals:

   4.1 Identify the important variables in a given physical problem.
   4.2. Develop appropriate strategies for solving physical problems using fundamental principles rather than secondary formulas.
   4.3. Successfully apply appropriate mathematical methods to obtain solutions.
   4.4. Evaluate solutions to determine if they are physically reasonable.
   4.5. Develop reasoning in three dimensions.

5. To provide an appreciation of the nature of physics, its methods and its goals.

   Learning Goals:

   5.1 Make connections between the atomic nature of matter and the behavior of macroscopic systems.
   5.2. Construct computational models to predict the time evolution of a particular system.
   5.3. Generate graphs to illustrate the correlation between different parameters.
   5.4. Become proficient in using commercial software, such as Excel, MatLab, or Mathematica, to plot data, conduct error and statistical analysis of data, and perform calculations on relatively large data sets.
   5.5. Understand how scientists support or rule out new ideas and add to the body of scientific knowledge.

6. To engage in productive communication and collaboration with peers.

   Learning Goals:

   6.1. Contribute productively to group discussions about physical phenomena and problems.
   6.2. Clearly articulate thoughts about how the natural world behaves.
   6.3. Use scientific reasoning and argumentation to defend one's ideas against competing ideas.
   6.4. Explain physical phenomena and mechanisms using both formal and informal language, as well as graphical, pictorial, mathematical, or other representations.

Course Outline

1. Relativity (Ch. 1 & 2)
   Principle of relativity. Michelson-Morley Experiment. Postulates of special relativity. Lorentz transformation. Time dilation and length contraction. Twin paradox. Relativistic momentum and energy. Mass as a measure of energy. Conservation of relativistic energy and momentum.
   Homework 1. (Chapter 1) 4, 5, 7, 10, 11, 13, 16, 21, 24, 25, 33.
   Homework 2 (Chapter 2) 1, 5, 9, 11, 14, 15, 19, 21, 23, 29, 31.

2. Quantum Theory of Light (Ch. 3)
   Light as an electromagnetic wave. Blackbody radiation. Planck's Law.
   Photoelectric effect. Compton effect. Particle-wave complementarity.
   Homework 3. (Chapter 3) 3, 4, 11, 13, 15, 19, 20, 25, 28, 31, 37, 47.

Test 1. (TBD)

3. Particle Nature of Matter (Ch. 4)
   Composition of atoms. Bohr atom. Bohr's correspondence principle. Franck-Hertz experiment.
   Homework 4. (Chapter 4) 3, 5, 13, 15, 17, 19, 32, 33, 39.

4. The Wavelike Properties of Particles (Ch. 5)
   The pilot waves of De Broglie. The Davisson experiment. Wave groups and dispersion. Fourier integrals. Heisenberg uncertainty principle. The wave-particle duality.
   Homework 5. (Chapter 5) 5, 7, 17, 19, 21, 23, 27, 33.

5. Quantum Mechanics in One Dimension (Ch. 6)
   The Born interpretation. Wavefunctions for a free particle and in the presence of forces. Schrödinger wave equation. Particle in a box. Finite square well. Quantum oscillator. Expectation values. Observables and operators.
   Homework 6. (Chapter 6) 1, 3, 5, 9, 13, 15, 17, 23, 29, 31.

Test 2. (TBD)

6. Tunneling Phenomena (Ch. 7)
   The square barrier. Barrier penetration: some applications.
   Homework 7. (Chapter 7) 1, 2, 3, 8, 9.

7. Quantum Mechanics in Three Dimensions (Ch. 8)
   Particle in a three dimensional box. Central forces and angular momentum. Space quantization. Quantization of angular momentum and energy. Atomic hydrogen and hydrogen-like atoms.
   Homework 8. (Chapter 8) 1, 3, 9, 11, 12, 13, 17, 21, 27, 28, 32.

8. Atomic Structure (Ch. 9)
   Orbital magnetism and the normal Zeeman effect. The spinning electron. The spin-orbital interaction. The exclusion principle. The periodic table. X-ray spectra and Moseley's law.
   Homework 9. (Chapter 9) 1, 3, 5, 7, 13, 21, 23.

Final Exam (TBD)

Laboratory

For the laboratory grade students must prepare one formal report (in LaTeX), have, at all times in lab, a lab notebook in which they must write all data, calculations, observations and procedures performed during the experiments. Students are expected to be in the lab on time, points will be deducted for tardiness. The formal lab report format and lab notebook expectations may be downloaded from CANVAS.

Lab. 1. Electronics Survey
Lab. 2. Speed of light.
Lab. 3. Physlets. Special relativity and Relativistic Mechanics
Lab. 4. Michelson Interferometer.
Lab. 5. Stefan-Boltzmann Law.
Lab. 6 Photoelectric effect.
Lab. 7. Bragg scattering and microwave two slit diffraction.
Lab. 8. e/m measurements.
Lab. 9. Wave behavior of electrons.
Lab. 10. Fast Fourier Transform of Electronic Signals.
Lab. 11. Models of the Hydrogen Atom.
Lab. 12. Hydrogen and quantum dots spectra.
Lab. 13. Quantum Mechanics Simulations: Bound States. Unbound states and Tunneling

Assessment of Student Performance

1. tests (35 points)
2. final exam (30 points)
3. homework problems (13 points)
   Homework problems are due one week after the corresponding chapter has been completed in the lectures unless otherwise noted. Late homework will not be accepted. Homework should be presented in an <u>ordered and neat presentation</u>; points will be deducted for lack of these.
4. lab work, lab notebook, and formal lab report (22 points)

Grading Scale	
Final Score	Letter Grade
92.5 - 100	A
89.5 – 92.4	A-
86.5 – 89.4	B+
82.5 – 86.4	B
79.5 – 82.4	B-
76.5 – 79.4	C+
72.5 – 76.4	C
69.5 – 72.4	C-
66.5 – 69.4	D+
59.5 – 66.4	D
0 – 59.4	F

Exam or Test Absences Policy

I. **Final Exam**: The final exam schedule is known well in advance. Serious personal illness and death in immediate family will be the only acceptable excuses. All students must follow the general guidelines stated below. All excused students must take their make-up final exam before 2:00 PM on the last day of the final exams, or they will receive an incomplete (I) or an F. It is the student's responsibility to request the make-up and provide a timely and acceptable proof.

II. **Tests:** You should make every effort to take the test at its scheduled date. If you cannot:
You must **inform** the instructor about the nature of your absence before the missed test (for non-emergency absences) or within 24 hours after the missed test (for emergency absences);
By the following class period you must show the instructor (or arrange to be shown) a **proof** that the absence is excusable**;** it is the student's responsibility to contact the instructor in a timely manner and provide an acceptable excuse.

III. **Excuses:**
Non-acceptable: Travel plans, weddings, lack of preparation, busy schedules; too many other obligations, assignments, or tests; job interviews, doctor's appointments or any other engagements or appointments that can be scheduled at different times, and alike, **will not be accepted** and the student will receive zero points for the test **- no exceptions**. The test dates are known ahead of time, so please plan accordingly.
Acceptable: Personal illness, death in one's family, and alike.

IV. **Taking the Make-Up:**
A student will be allowed to take a make-up only for an excused absence;
Unless otherwise stated in writing by her/his physician, s/he must take the make-up **within seven days** of the missed examination.
If the student fails to inform the instructor, does not provide an acceptable proof, or does not take the make-up in a timely manner, s/he will be given zero.
The make-ups will be **different** from regular examination, so **timely notification** of the instructor is essential.

Fourth Hour:

In this class, the deep learning outcomes associated with TCNJ's 4th hour are accomplished by a series of rigorous educational assignments that extend beyond the typical scheduled class time. These include activities conducted in the scheduled laboratory section, out-of-class problem sets, and out-of-class online learning activities such as video lectures and reading assignments.

Additional Resources

R. P. Feynman, *"Lectures on Physics,"* Addison-Wesley (1965).
K. Krane, "*Modern Physics,"* 3rd ed. J. Wiley (2012).
P. Tipler & R. Llewellyn, "*Modern Physics*", 6th Ed, W. H. Freeman and Co., New York
S. T. Thornton and A. Rex, *"Modern Physics for Scientists and Engineers,"* 4th ed. Brooks/Cole CENGAGE Learning (2006).

SELECTED TCNJ POLICIES

Final Examinations

The final exam is not scheduled until the middle of the semester. Therefore do not plan on any travel until after the last day of the exam period. TCNJ's final examination policy is available on the web:

http://policies.tcnj.edu/policies/digest.php?docId=9396

Attendance

Every student is expected to participate in each of his/her courses through regular attendance at all class sessions. It is further expected that every student will be present, on time, and prepared to participate when scheduled class sessions begin. While attendance itself is not used as a criterion for academic evaluations, grading in this course is based on participation in quizzes to be given at the beginning of several classes. No make-ups or extensions will be given unless a student has a genuine emergency. If a student misses an exam or assignment deadline they must contact the instructor within 36 hours to explain the situation; otherwise the student will earn a zero for that exam or assignment.
Students who must miss classes due to participation in a field trip, athletic event, or other official college function or for a religious holiday should arrange with their instructors for such class absences well in advance. In every instance, however, the student has the responsibility to initiate arrangements for make-up work.

TCNJ's full attendance policy is available at: **http://policies.tcnj.edu/policies/digest.php?docId=9134**

Academic Integrity Policy

Academic dishonesty is any attempt by the student to gain academic advantage through dishonest means, to submit, as his or her own, work which has not been done by him/her or to give improper aid to another student in the completion of an assignment. Such dishonesty would include, but is not limited to: submitting as his/her own a project, paper, problem set, report, test, or speech copied from, partially copied, or paraphrased from the work of another (whether the source is printed, under copyright, or in manuscript form). Credit must be given for words quoted or paraphrased. The rules apply to any academic dishonesty, whether the work is graded or ungraded, group or individual, written or oral.
TCNJ's academic integrity policy is available at:
http://policies.tcnj.edu/policies/digest.php?docId=9394

Americans with Disabilities Act (ADA) Policy

Any student who has a documented disability and is in need of academic accommodations should notify the professor of this course and contact the Office of Differing Abilities Services (609-771-2571). Accommodations are individualized and in accordance with Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1992.TCNJ's Americans with Disabilities Act (ADA) policy is available at: **http://affirm.pages.tcnj.edu/files/2011/08/Americans-with-Disabilities-Act-4.7.10.docx**