Modern Physics

PHY 321

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Days and times of scheduled office/student hours:
Tuesdays: 11:00 a.m. - 1:00 p.m., Wednesdays 11:00 a.m. - 12:00 p.m.
All communication outside of class should be handled by email: ochoa@tcnj.edu
Expectations for response times: 24 hours on weekdays, 48 hours on weekends.

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: S. T. Thornton, A. Rex, C. Hood, "Modern Physics," 5th Edition, Cengage Learning (2021).
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. Special Relativity (Ch. 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. WebAssign Chapter 2

2. Experimental Basis of Quantum Physics (Ch. 3)
   Determination of electron charge. Light as an electromagnetic wave. Line spectra. Blackbody radiation. Planck's Law. Photoelectric effect. X ray discovery and production. Compton effect. Particle-wave complementarity.
   Homework 2. WebAssign Chapter 3

3. Structure of the Atom (Ch. 4)
   Composition of atoms. Bohr atom. Bohr's correspondence principle. Atomic excitation by electrons – the Franck-Hertz experiment.
   Homework 3. WebAssign Chapter 4

4. Wave Properties of Matter and Quantum Mechanics I (Ch. 5)
   Bragg's law. The pilot waves of De Broglie. Electron scattering - the Davisson experiment. Wave groups and dispersion. Heisenberg uncertainty principle. The wave-particle duality. The Born interpretation. The Copenhagen interpretation.
   Homework 5. WebAssign Chapter 5

5. Quantum Mechanics II (Ch. 6)
   Schrödinger wave equation. Expectation values. Observables and operators. Particle in a box. Finite square well. Particle in a three-dimensional box. Quantum oscillator. Barriers and tunneling. The square barrier. Barrier penetration: some applications.

   Homework 6. WebAssign Chapter 6

6. The Hydrogen Atom (Ch. 7)
   Central forces and angular momentum. Atomic hydrogen and hydrogen-like atoms. Space quantization. Quantization of angular momentum and energy. Magnetic effects on atomic spectra – the normal Zeeman effect. Intrinsic spin. Energy levels and electron probabilities.
   Homework 8. WebAssign Chapter 7

Laboratory

An electronic lab notebook will be kept (in a Google Drive file), per group of students, in which they must write all data, calculations, and results obtained during the experiments.

Lab. 1. Electronic Survey

Lab. 2. Measuring the speed of light.
Lab. 3. Michelson interferometer
Lab. 4. Special relativity kinematic and dynamic simulations.
Lab. 5. Stephan Boltzmann law.
Lab. 6. Photoelectric effect.
Lab. 7. Bragg scattering with microwaves.
Lab. 8. e/m measurements.
Lab. 9. Wave behavior of electrons.
Lab. 10. Fast Fourier transforms of electronic signals.
Lab. 11. Classical models of the Hydrogen atom.
Lab. 12. Hydrogen gas spectra and quantum dots spectra.
Lab. 13. Quantum models of the Hydrogen atom.

Assessment of Student Performance

1. tests (35 points)
2. final exam (30 points)
3. Homework problems (12 points)
4. Lab work and lab notebook (20 points)
5. Class participation + clicker polls (3 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, at least two weeks before the final is scheduled.

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

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**

LINKS TO SELECTED TCNJ POLICIES

Academic Integrity
Americans with Disabilities Act (ADA)
Anti-Discrimination Policy
Remote Classroom Camera/Mic and Recording Policy