PHYS 4D: GENERAL PHYSICS (CALCULUS)

Foothill College Course Outline of Record

Heading	Value
Effective Term:	Summer 2025
Units:	6
Hours:	5 lecture, 3 laboratory per week (96 total per quarter)
Prerequisite:	PHYS 4C.
Corequisite:	Completion of or concurrent enrollment in MATH 2A.
Degree & Credit Status:	Degree-Applicable Credit Course
Foothill GE:	Non-GE
Transferable:	CSU/UC
Grade Type:	Letter Grade (Request for Pass/No Pass)
Repeatability:	Not Repeatable

Student Learning Outcomes

- Students should have both a conceptual and computational understanding of Einstein's theory of special relativity.
- The lab experiments should give students deeper understanding into the historical experiments that form the basis of modern physics and the science involved.
- Students should have an understanding of the Schrodinger Equation and be able to solve problems with introductory-level potentials.

Description

Special relativity, statistical mechanics, quantum mechanics, atomic physics, nuclear physics, particle physics.

Course Objectives

The student will be able to:

1. Compute special relativity problems and interpret related paradoxes and special cases.
2. Explain wave-particle duality and its implications through both historical and thought experiments.
3. Discuss the concepts of quantum mechanics and solve simple problems.
4. Discuss models and solve problems pertaining to the hydrogen atom, the periodic table, and condensed matter physics.
5. Explain models of nuclear physics and how they relate to observed results, and solve problems concerning radioactive decay.
6. Explain current theories in particle physics.
7. Discuss historical and current barriers to access in physics.

Course Content

1. Compute special relativity problems and interpret related paradoxes and special cases
    a. Frames of reference
        i. Inertial vs. noninertial frames
        ii. Galilean transforms
    b. The speed of light
        i. Maxwell's equations
        ii. Ether
        iii. Michelson-Morley results
    c. Einstein's postulates
        i. Laws of physics same in inertial frames
        ii. Speed of light constant in inertial frames
    d. Lorentz transformations
        i. Length contraction
        ii. Time dilation
        iii. Simultaneity
        iv. Experimental evidence
            1. Muon decay
            2. Airborne atomic clocks
    e. Paradoxes
        i. Twin paradox
        ii. Ladder in barn paradox
    f. Addition of velocities
    g. Momentum
        i. Momentum is conserved
        ii. Discussion of "relativistic mass"
    h. Energy
        i. Derivation of e=mc^2
        ii. Conservation of energy
        iii. Relativistic collisions
    i. General relativity
2. Explain wave-particle duality and its implications through both historical and thought experiments
    a. Light acting like a particle
        i. Blackbody radiation
            1. Definition of a black body
            2. Wien's law
            3. T^4 law
            4. Classical attempts at solution
            5. Planck's solution
        ii. The photoelectric effect
            1. Experimental evidence
            2. Einstein's solution
        iii. The Compton effect
    b. Wave properties of particles
        i. The de Broglie hypothesis
        ii. Electron diffraction
    c. Wave-particle duality
        i. Two slit experiments
            1. Predictions for waves
            2. Predictions for particles
            3. Experimental results
        ii. The concept of probabilistic results
3. Discuss the concepts of quantum mechanics and solve simple problems

- a. The Stern-Gerlach experiment
  - i. The concept of spin
  - ii. Experimental results
    - 1. Alignment and anti-alignment
    - 2. Results of consecutive measurements
  - iii. Mathematical representation
    - 1. State vectors
    - 2. Eigenvectors
    - 3. The collapse of the state vector
    - 4. Assignment of probability based upon amplitude
    - 5. Normalization of recombined waves
    - 6. Time evolution
- b. Wave functions and the Schrodinger equation
  - i. Justification of the Schrodinger equation
    - 1. Probability results
    - 2. Energy eigenfunctions
  - ii. Heisenberg uncertainty principle
  - iii. Particle in a box
    - 1. Infinite walls
      - a. Solutions
      - b. Quantized energy levels
    - 2. Finite box
    - 3. Two-dimensional box
  - iv. Scattering and tunneling
  - v. Quantum harmonic oscillator
  - vi. Correspondence principle

4. Discuss models and solve problems pertaining to the hydrogen atom, the periodic table, and condensed matter physics
   - a. Bohr's model of the hydrogen atom and the hydrogen spectrum
     - i. Restriction of angular momentum to integer multiples of Planck's constant
     - ii. Bohr radius
     - iii. Energy levels and the hydrogen spectrum
     - iv. Shortcomings of the Bohr model
   - b. Quantum mechanical approach
     - i. Schrodinger's equation
       - 1. Three dimensions
       - 2. Electrostatic potential
       - 3. Spherical coordinates
       - 4. Separation of variables
     - ii. The need for four quantum numbers
     - iii. Wave functions for the hydrogen atom
       - 1. Shapes
       - 2. Probabilities
     - iv. Pauli exclusion principle
     - v. The periodic table
     - vi. Wave functions in solid state
       - 1. Energy bands
       - 2. Statistical distribution functions
5. Explain models of nuclear physics, how they relate to observed results, and solve problems concerning radioactive decay
   - a. Models of the nucleus
     - i. Stability
     - ii. Ratio of protons to neutrons
   - b. Radioactivity
     - i. Decay and half-lives
     - ii. Biological effects of radiation
   - c. Fission
   - d. Fusion
6. Explain current theories in particle physics
   - a. Inventory of particles
     - i. Leptons
     - ii. Hadrons
       - 1. Baryons
       - 2. Mesons
   - b. Conservation laws
   - c. Quarks
     - i. Eightfold way
     - ii. Color
   - d. Particles as force mediators
     - i. Virtual particles
     - ii. Different views of the strong force
7. Understand issues around access to physics
   - a. Discuss that historically our field has had barriers to entry due to race, gender, sexuality, class, and other factors
   - b. Discuss "hidden figures" in our field
   - c. Discuss that many of these issues persist to the current day and detail efforts to address them

Lab Content

Suggested laboratory experiments (some experiments may use computer-generated data and/or data from audio-visual media):

1. Exponential decay
2. Time dilation
3. The photoelectric effect (2 weeks)
4. Black body radiation
5. Atomic spectra
6. The Franck-Hertz experiment
7. Radioactive decay
8. Electron diffraction
9. Particle physics simulation

Special Facilities and/or Equipment

Physics laboratory with equipment for teaching introductory relativity and modern physics.

Method(s) of Evaluation

Methods of Evaluation may include but are not limited to the following:

Weekly problem sets
Laboratory performance
Periodic midterm tests
Weekly quizzes
Projects/presentations
Final examination
Students are evaluated using a variety of measures that can include written exams, project presentations, and discussions, in order to allow them to demonstrate their knowledge and skills by the end of the quarter

Method(s) of Instruction

Methods of Instruction may include but are not limited to the following:

Lecture (may be live/interactive or in the form of pre-recorded videos)
Discussion
Cooperative learning exercises
Laboratory
Demonstration
Students gain an understanding of physics through connecting new terms, concepts, and procedures to what they already know through small group and large group discussions, making predictions and correcting each other's assumptions on ranking tasks, and practicing problem solving methods with the support and guidance of peers and the instructor

Representative Text(s) and Other Materials

Moebs, Ling, and Sanny. University Physics (OpenStax). 2017.

This is the standard OER text in the field. It is supported by OpenStax/ Rice University. Additionally, the bulk of the material in the course was discovered between 1905 and the 1980s, and there has not been much development since.

Types and/or Examples of Required Reading, Writing, and Outside of Class Assignments

1. Homework problems: Homework problems covering subject matter from text and related material ranging from 10-20 problems per week. Students will need to employ critical thinking in order to complete assignments.
2. Lecture: Five hours per week of lecture covering subject matter from text and related material. Reading and study of the textbook, related materials, and notes.
3. Labs: Students will perform experiments and discuss their results either in the form of a written lab report or via oral examination. Reading and understanding the lab manual prior to class is essential to success.

Discipline(s)

Physics/Astronomy