

Syllabus: Pre-AP Physics I

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Overview

In general, physics is the scientific study of the properties and interactions of matter and energy. Physics has qualitative, quantitative, empirical, and theoretical aspects and relies upon mathematical descriptions of nature. In this course, we will emphasize organized and logical approaches to problem solving, and direct observation, analysis, and interpretation of natural physical phenomena through laboratory studies. This course will also explore the significance of scientific methods and physical principles to technology, daily life, the economy, and ultimately, our civilization.

Course Objectives and Instructor Philosophy

Although knowledge of specific facts and concepts is important, science education must focus primarily on developing logical, systematic, and rigorous approaches to inquiry and problem solving. In this course, I will place emphasis upon learning to think scientifically—namely, developing a questioning habit of mind, and learning to formulate hypotheses and devising appropriate tests for these hypotheses. Course topics will generally be taught in a historical way. We will see how physicists of the past addressed outstanding scientific questions of their times. In this way, we will gain an understanding of a broad range of scientific methodologies from pure description to thought experimentation and experimental laboratory methods.

Mathematical Considerations

In general, Pre-AP Physics I is an algebra-based investigation of elementary physics concepts. However, from time to time the methodologies of calculus and vector analysis are so powerful and illuminating that I use them in solving problems—many in the class will have a working knowledge of these concepts (especially

those in Mr. French's Calculus class!). Students in the Pre-AP course may rest assured, however, that I will explain any unfamiliar mathematics used, and that I will not hold them accountable for advanced or exotic mathematical concepts beyond the level of ordinary algebra and trigonometry.

Topical Course Outline

I. Introduction

- A. General expectations for student performance during the course
- B. Measurement, uncertainty, and analysis (e.g., SI units, dimensional analysis, significant figures and absolute precision)
- C. Mathematics review: vectors and scalars
 - 1. Resolution of vector components (with trigonometry review)
 - 2. Vector multiplication
 - a. Scalar multiples of vector quantities
 - b. Dot products
 - c. Cross products

II. Scientific methods

- A. What is science?
- B. Qualitative, quantitative, and empirical methods
- C. Falsifiability: hypotheses, theories, and scientific laws

III. Newtonian (Classical) mechanics

- A. Kinematics
 - 1. Motion in one dimension
 - a. Distance and displacement
 - b. Speed and velocity
 - c. Acceleration
 - d. Position function and equations of motion
 - e. Relative motion
 - 2. Motion in two dimensions, including projectiles
- B. Dynamics and Newton's laws of motion
 - 1. Static equilibrium and the law of inertia (1st law)
 - 2. Dynamics of a single particle: $\mathbf{F} = m\mathbf{a}$ (2nd law)

3. Action-reaction principle/systems of two or more objects (3rd law)
 4. Types of forces
 - a. Fundamental forces (field forces)
 - b. Mechanical forces (e.g., Hooke's law)
 - c. Conservative versus nonconservative (e.g., frictional) forces
- C. Work, energy, power
1. Work-energy theorem
 2. Potential energy
 3. Kinetic energy
 4. Mechanical energy
 5. Conservation of energy
 6. Power
- D. Systems of particles and linear momentum
1. Center of mass
 2. Impulse
 3. Elastic and inelastic collisions
 4. Conservation of linear momentum
- E. Circular motion and rotation
1. Uniform circular motion: centripetal acceleration and force ("force that maintains circulation")
 2. Rotational kinematics
 - a. Angular displacement
 - b. Angular speed and velocity
 - c. Angular acceleration
 - d. Position function and equations of rotational motion
 3. Rotational dynamics
 - a. Moment of inertia
 - b. Torque and rotational equilibrium
 - c. Newton's laws for rotation
 - d. Angular momentum and its conservation
- F. Gravitation

1. Kepler's laws of planetary motion and the conic sections
 2. Newton's law of universal gravitation
 - G. Oscillations and simple harmonic motion (dynamics and energy relationships)
 1. Mass on a spring
 2. Pendulum and other oscillators
- IV. Fluid mechanics
- A. Hydrostatic pressure, equilibrium, and isostasy
 - B. Buoyancy
 - C. Fluid flow continuity equation
 - D. Bernoulli's equation
- V. Thermal Physics
- A. Temperature and heat
 1. Mechanical equivalent of heat
 2. Heat transfer and thermal expansion
 - B. Kinetic theory and thermodynamics
 1. Ideal gases
 - a. Kinetic model
 - b. Ideal gas law
 2. Thermodynamic processes and the laws of thermodynamics
 - a. Thermal equilibrium
 - b. Isovolumetric, isothermal, isobaric, and adiabatic processes
 - c. First law (with pressure-volume phase diagrams)
 - d. Entropy principle and the Second law the (with heat engines and the Carnot cycle)
- VI. Waves and Optics
- A. Wave motion
 1. Traveling waves
 - a. Anatomy of waves: amplitude, wavelength, etc.
 - b. Doppler effect
 2. Wave propagation

- a. Wave types: longitudinal (e.g., sound) and transverse (e.g., light)
- b. Intensity
- c. Polarization
- 3. Standing waves
 - a. Harmonics
 - b. Resonance
- 4. Superposition principle

B. Physical optics

- 1. Interference: constructive and destructive
 - a. Single slit
 - b. Double slit
 - c. Interferometers and the Michelson-Morley experiment
 - d. Thin films
- 2. Diffraction
- 3. Dispersion
- 4. Electromagnetic spectrum

C. Geometric optics and ray diagrams

- 1. Reflection
 - a. Plane mirror
 - b. Spherical and other mirrors
 - c. Law of reflection
 - d. Image types, magnification
- 2. Refraction
 - a. Snell's law
 - b. Lenses
 - 1. Concave
 - 2. Convex
- 3. Thin lens/mirror equation with sign conventions

VII. Electricity and magnetism

A. Electrostatics

- 1. Electric charge and Coulomb's law
- 2. Conductors and insulators

3. Electric fields, potentials, and potential energy (around point charges and other objects)
 4. Gauss's law
- B. Capacitors
1. Capacitance
 2. Parallel plate and other geometries (cylindrical, etc.)
 3. Dielectrics
- C. Electric circuits
1. Electric battery
 2. Direct current, resistance (and resistivity), and voltage: Ohm's law and electric power
 3. Direct series circuits (batteries and resistors only)
 4. Direct parallel circuits (batteries and resistors only)
 5. Direct combination circuits (batteries and resistors only)
 6. RC circuits
 - a. Steady state
 - b. Charging and discharging (transients)
- D. Magnetic fields
1. Magnetic polarity and field geometry
 2. Gauss's law for magnetic fields
- E. Electromagnetism
1. Magnetic fields around wires with current: Ampere's law (and the Biot-Savart law)
 2. Lorentz force (forces on charges moving through space and through wires)
 3. Electromagnetic induction (Faraday's and Lenz's laws): electric generators and motors and ac currents
 4. Coils and inductance (LR and LC circuits)
 5. Synthesis: Maxwell's equations
 - a) Gauss's law for electric fields
 - b) Gauss's law for magnetic fields
 - c) Faraday's law of electromagnetic induction
 - d) Ampere-Maxwell law (with displacement currents)

e) Maxwell's concept of the electromagnetic wave

VIII. Modern Physics

A. Quantum physics: atoms, nuclei, particles; photons

1. Cavity radiation: Planck's quantum hypothesis
2. Photoelectric effect and photons
3. Compton scattering
4. Atomic structure
 - a. Greek theories
 - b. Dalton
 - c. Thomson
 - d. Rutherford
 - e. Bohr: quantized energy and angular momentum
5. de Broglie: matter waves and particle-wave duality
6. Heisenberg uncertainty principle
7. Nuclear physics
 - a. Nuclear forces (strong and weak)
 - b. Nuclear reactions: modes of radioactive decay; fission and fusion

B. Einstein's special theory of relativity

1. Einstein's postulates
2. Time dilation
3. Fitzgerald (length) contraction
5. Mass-increase
6. Mass-energy equivalence

Evaluation Methods

In general, there are two kinds of grades in this class, "daily" and "major." "Daily" grades include homework, quizzes, and labs. "Major" grades include test and projects. Daily and major grades are each worth 50%.