

Physics Subject Matter Requirements

Content Domains for Subject Matter Understanding and Skill in Physics

Domain 1. Motion and Stability: Forces and Interactions

1.1 Understand forces and motion.

- a. Use Newton's law of universal gravitation and Coulomb's law to describe and predict the effects of gravitational energy and electrostatic forces between distant objects.
- b. Solve problems using Newton's laws of motion and universal gravitation (e.g., problems involving time, velocity, and space-dependent forces).
- c. Analyze free body diagrams of many-body problems (e.g., problems involving two or more coupled masses).
- d. Solve periodic motion problems, including problems involving simple harmonic motion.
- e. Solve two-dimensional problems involving vector analysis of motion and forces, including projectile motion, uniform circular motion, and statics.
- f. Analyze functional relationships of graphs showing distance, velocity, and acceleration versus time (e.g., evaluating slopes and areas using algebra and calculus).
- g. Demonstrate knowledge of relationships among variables for linear motion and rotational motion, including solving problems involving linear and rotational motion in terms of forces and torques.
- h. Evaluate the relative motion of systems of objects.
- i. Evaluate the statics and dynamics of Newtonian fluids.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS2.A, PS2.B)

1.2 Understand conservation of energy and momentum.

- a. Differentiate between kinetic energy and potential energy and demonstrate knowledge of the variables in these states of energy.
- b. Analyze kinetic-potential energy systems such as oscillating systems (pendula and springs), projectile motion, and roller coasters in terms of conservation of energy, including analyzing graphs.
- c. Analyze elastic and inelastic collisions and solve problems involving collision for unknown values.
- d. Solve problems involving linear and rotational motion in terms of conservation of momentum and energy.
- e. Analyze relationships between energy/momentum conservation principles and Newton's laws.
- f. Demonstrate knowledge of the impact of retarding forces (e.g., friction, air resistance) on conservation principles.
- g. Analyze force-versus-time and force-versus-distance graphs (e.g., to find work done or impulse on a system).
- h. Solve problems involving momentum quantities in two dimensions.

- i. Solve problems involving moment of inertia of standard geometric objects, including objects requiring the use of the parallel axis theorem.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS2.A, PS3.B)

Domain 2. Energy

2.1 Understand definitions of energy and energy in everyday life.

- a. Analyze the energy in a system, including describing energy in terms of the motion and interactions of matter and radiation and recognizing that energy in systems is continually transferred from one object to another and between its possible forms (e.g., kinetic, potential).
- b. Demonstrate knowledge of how different manifestations of energy (e.g., sound, light, thermal energy) can be modeled as a combination of energy associated with the motion of particles and energy associated with the relative position of these particles.
- c. Apply knowledge of the benefits and hazards of the use of radiation, radioactivity, and nuclear energy in comparison to nonnuclear processes.
- d. Analyze electric power generation from fossil fuels and alternative sources (e.g., solar, wind, tidal, geothermal, hydro) and compare their relative efficiencies.
- e. Analyze energy transformations in systems, including identifying factors that contribute to inefficiencies in energy transfer (e.g., all types of heat loss).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS3.A, PS3.B, PS3.D)

2.2 Understand thermal energy and kinetic molecular theory.

- a. Apply knowledge of the laws of thermodynamics using the relationships among work, heat, energy, and entropy, including solving thermodynamic problems.
- b. Solve problems using the thermodynamic properties of materials (e.g., kinetic theory of matter, specific heat [heat capacity], heats of fusion and vaporization, thermal conductivity, thermal expansion).
- c. Apply knowledge about ideal gas systems, including solving problems involving ideal gas systems.
- d. Analyze graphs and solve problems involving phase changes, cyclic processes, work done, heat gain/loss, and entropy change.
- e. Demonstrate knowledge of a plasma, state its characteristic properties, and contrast it with an ideal gas.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS3.B)

2.3 Understand electricity and magnetism.

- a. Analyze electric and magnetic forces, charge, and fields using Coulomb's law, the Lorentz force, and the right-hand rule.
- b. Apply energy principles to analyze problems in electricity, magnetism, and circuit theory involving capacitors, resistors, and inductors.
- c. Apply knowledge of power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors, and solve problems involving such circuits.
- d. Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors.
- e. Apply knowledge of and explain the relativistic relationship between electric and magnetic phenomena.
- f. Solve problems involving the change of magnetic flux and induced current.
- g. Demonstrate knowledge of properties of transistors, diodes, and semiconductors.
- h. Apply knowledge of electric potential energy.
- i. Determine the electric field flux through a surface for systems with a uniform distribution of charge using Gauss's law.
- j. Analyze capacitors in terms of geometry, dielectrics, charge, and energy storage.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS2.B, PS3.B)

Domain 3. Waves and Their Applications

3.1 Understand wave properties.

- a. Explain the relationship between the wavelength, frequency, and speed of travel of a wave.
- b. Demonstrate knowledge of the properties of waves, including the relationship between amplitude and energy.
- c. Analyze wave propagation with respect to properties of materials (e.g., predicting wave speed from density and tension and index of refraction).
- d. Describe, distinguish, and solve both conceptual and numerical problems involving interference (e.g., constructive, destructive, resonance, thin film), diffraction (e.g., around edges, single-slit, double-slit), and refraction (e.g., the use of Snell's law, critical angle calculation, thin lens equation, ray diagrams).
- e. Describe, distinguish, and solve both conceptual and numerical problems involving reflection (with both plane and curved mirrors), Doppler effect, polarization, dispersion, and scattering.
- f. Analyze systems where standing waves are present (e.g., close-ended air columns, open-ended air columns, wires under tension).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS4.A)

3.2 Understand electromagnetic radiation and applications of waves in information technologies and instrumentation.

- a. Apply knowledge of the wave and particle models that explain the properties of electromagnetic radiation, including evidence supporting these models (e.g., black-body radiation, double-slit experiment).
- b. Demonstrate knowledge of the effects of different frequencies of electromagnetic radiation (e.g., light, ultraviolet, X-rays, gamma rays) when absorbed by matter, including living cells.
- c. Apply knowledge of the photoelectric effect, including the effects of varying frequencies of light on photoelectric materials.
- d. Demonstrate knowledge of how energy and information are transferred by waves without mass transfer, the technological devices and applications associated with waves (e.g., cell phones, medical imaging, telescopes), and the advantages and disadvantages of digital transmission and storage.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS4.B, PS4.C)

Domain 4. Modern Physics

4.1 Understand quantum mechanics, the standard model of particles, and special relativity.

- a. Analyze the four fundamental forces of nature, demonstrate knowledge of their ranges, and identify their force carriers.
- b. Analyze the assumptions and relevance of the Bohr model of the atom.
- c. Demonstrate knowledge of the basic principles of special relativity and their applications (e.g., Global Positioning System).
- d. Demonstrate knowledge of the basic principles of quantum mechanics (e.g., Heisenberg uncertainty principle, wave-particle duality).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.A)

4.2 Understand nuclear processes.

- a. Analyze mass-energy relationships in nuclear reactions and radioactive decay.
- b. Compare and contrast alpha, beta, and gamma decay, and their effects on living matter.
- c. Perform calculations involving half-life and binding energy.
- d. Apply knowledge of the processes of nuclear fission and nuclear fusion.
- e. Demonstrate the ability to balance nuclear reactions.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.C)

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