|  | **Required Course Numbers** |
| --- | --- |
| **Test Content Categories**  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| I . Nature and Impact of Science and Engineering |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Nature of Science
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Nature of scientific knowledge
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Involves a variety of investigation methods
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Based on experimental evidence that is reproducible
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Major concepts develop and change over time in light of new evidence
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Constructing and testing hypotheses
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Explain natural phenomena by using existing models and theories
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Developing, using, evaluating, and revising models
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Involves process skills, including observing, categorizing, comparing, generalizing, inferring, concluding, and communicating
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Experimental design, data collection, and analysis
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Standard units of measurement, dimensional analysis, and unit conversion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Scientific notation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Vector and scalar quantities including vector addition (graphical and mathematical)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Experimental design, including developing and using models, identifying variables, planning data collection, and supporting the testing of the hypothesis
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Processing data using mathematical and computational thinking, organizing data, and reporting data
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Error analysis, including accuracy and precision, means, and percent error
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Identifying sources and effects of error
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interpreting and drawing conclusions from data
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Laboratory procedures
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Appropriate preparation, use, storage, and disposal of materials
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Appropriate use of laboratory and measurement equipment, including selection, calibration, and maintenance
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Safety procedures and precautions for the laboratory
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Science, Engineering, Technology, Society, and the Environment
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interdependence of science, engineering, and technology
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engineering advances lead to important discoveries in science (e.g., telescopes, lasers, super collider)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Science and technology drive each other forward (e.g., in communications with wireless devices, in medicine with imaging, in transportation with superconductors and magnetic levitation)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Ethics, values, and social and cultural circumstances impact how scientific advances are utilized
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Application of the engineering design process to the physics classroom
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Defining problems, including identifying the criteria and the constraints
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Designing solutions, including proposing and evaluating in terms of criteria, constraints, and limitations
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Optimizing the design, including systematic modification and refinement
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Real-world environmental and societal problems impacted by technology or subject to solution through engineering design
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Environmental (e.g., climate change, ozone layer depletion, noise pollution)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Sustainability (e.g., production, reduction, reusing, and recycling of consumer goods)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Energy (e.g., renewable and nonrenewable energy resources)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| II. Principles and Models of Matter and Energy |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conceptual Understanding of Atomic and Nuclear Structure and Processes
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Atomic and subatomic structures
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Atomic components (protons, neutrons, and electrons)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Bohr model
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationship between atomic spectra and electron energy levels
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electron energy transitions in atoms
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Absorption and emission spectra
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics and effects of nuclear processes
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Radioactivity and radioactive decay processes, including half-life
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Alpha particles, beta particles, and gamma radiation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Fission and fusion (conservation of mass energy, charge, and nucleons)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic quantum physics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Wave-particle duality of matter and electromagnetic energy
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Photoelectric effect
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationships Between Energy and Matter
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Temperature, forms of energy, heating, and heat capacity
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Temperature as a measure of average kinetic energy
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Distinguish between temperature, heating, and thermal energy
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Heat capacity, specific heat, and latent heat
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Thermal mechanisms of energy transfer (conduction, convection, radiation)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Meaning and use of different temperature scales (Kelvin, Celsius, Fahrenheit)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conceptual relationships of thermodynamics to physical processes
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of energy for thermal processes (first law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Entropy does not decrease in a closed system (second law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Absolute zero (third law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Thermal equilibrium (zeroth law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| III. Mechanics |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic Concepts and Applications of Forces and Motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Description of motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Properties of scalar quantities (e.g., distance, mass, speed, time, energy)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Properties of vector quantities (e.g., displacement, velocity, acceleration, force, momentum)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Linear motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Two-dimensional motion (e.g., projectile motion)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Graphical analysis of motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Circular motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Simple harmonic motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Frames of reference and their applications
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Frames of reference (coordinate systems, inertial reference frames)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relative velocity
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Newton’s laws of motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. First law (mass, inertia, inertial reference frame)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Second law (net force, mass, acceleration)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Third law
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Gravitation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Newton’s law of universal gravitation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Satellites and orbital motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Acceleration due to gravity and gravitational field
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Weight, mass, and density
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationship between weight and mass
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationship between density and mass
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Kepler’s laws of orbital motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. First law (elliptical orbits)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Second law (equal areas in equal times)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Third law (relationship between orbital period and mean orbital radius)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic fluid mechanics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Fluid statics (buoyancy, density, pressure)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Fluid dynamics (Bernoulli’s principle and the continuity equation)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Advanced Concepts and Applications in Mechanics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Friction
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Normal force and frictional force
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Coefficients of static and kinetic friction Mechanisms of evolution
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Uniform circular motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Net force directed toward the center
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Centripetal acceleration
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Harmonic motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Restoring force (Hooke’s law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Period, frequency, amplitude
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Pendulums and spring oscillation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Energy
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Mechanical energy (kinetic and potential)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of energy, including energy transfers and transformations
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Work and power
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Linear momentum and impulse
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Center of mass
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Linear momentum and its conservation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Change in momentum (impulse)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Rotational motion
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Angular displacement, velocity, and acceleration
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Angular momentum and conservation of angular momentum
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Rotational inertia (moment of inertia)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Torque
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Static equilibrium
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Collisions
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Elastic and inelastic collisions
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of momentum
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of mechanical energy
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Collisions in one and two dimensions
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| IV. Electricity and Magnetism |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electricity
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electrostatics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electric charge and induced charge
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of charge, including charge transfer
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Coulomb’s law and point charges
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electric forces and electric fields
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electric potential, energy, and potential difference
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conductors and insulators
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electrical properties
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Material examples
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Properties and relationships involving electric current and capacitance
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Current, resistance, potential difference, and resistivity
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Ohm’s law
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Energy and power
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Direct current and alternating current
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Capacitance and capacitors
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Analysis of simple and combination circuits
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Series, parallel, and combination circuits
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Ohm’s law
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Equivalent resistance and capacitance
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Kirchhoff’s laws
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Power
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Generation of electrical potential
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Sources (Batteries, photocells, generators)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electromotive force (E​M​F)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetism
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetic fields, forces, and materials
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetic field and magnetic flux
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetic force
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnets (bar magnets and poles, permanent magnets, electromagnets)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Transformers, motors, and generators
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Direction of fields and forces (right-hand rules)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetic field generated by steady current (Biot-Savart law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Force between current-carrying wires
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Force on moving charges in magnetic fields (Lorentz force)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic conceptual relationships between electric fields and magnetic fields
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetic field caused by changing electric field (Ampere’s law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Direction of induced current caused by changing magnetic field (Lenz’s law)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Induced E​M​F (Faraday’s law of induction)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. E​M​F (due to motion of conductor)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| V. Waves |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conceptual Understanding of Wave Characteristics and Phenomena
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Types of waves and their characteristics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Transverse and longitudinal
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Mechanical and electromagnetic
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationships between amplitude, wavelength, frequency, period, speed of propagation, and energy
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Superposition and phase
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Intensity
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Spherical and plane waves
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Standing waves
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Wave phenomena
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Reflection, refraction (including Snell’s law), and total internal reflection
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Diffraction, interference and Young’s double-slit interference experiment
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Polarization
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Scattering, absorption, dispersion, and transmission
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Resonance and natural frequencies, harmonics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Doppler effect (moving source or observer)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electromagnetic Waves, Sound, and Geometric Optics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electromagnetic waves and the electromagnetic spectrum
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electromagnetic waves (electric and magnetic fields, speed of light, energy)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, x-rays, gamma rays)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. The visible spectrum (red, orange, yellow, green, blue, violet)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Applications of the Doppler effect involving electromagnetic waves
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Sound
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Compression waves
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Speed of sound (sonic boom and sound barrier)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Pitch (frequency) and loudness (intensity)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Beats
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Resonance (open and closed pipes; strings)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Applications of Doppler effect involving sound
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Geometric optics
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Ray tracing
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Focal point, image distance, image size and magnification, real versus virtual image, image orientation
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Lenses (converging and diverging)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Mirrors (plane, convex, concave)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Simple instruments (magnifying glass, telescope, microscope, prisms)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Science and Engineering Practices** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| The S​E​Ps represent eight practices that scientists and engineers—and students and teachers—use to investigate the world and to design and build systems. Many test questions will integrate one or more of these practices. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Asking questions (for science) and defining problems (for engineering)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions to clarify and refine a model, an explanation, or an engineering problem.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Developing and using models
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Design a test of a model to ascertain its reliability.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
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| * Develop a complex model that allows for manipulation and testing of a proposed process or system.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Planning and carrying out investigations
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation’s design to ensure variables are controlled.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Select appropriate tools to collect, record, analyze, and evaluate data.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Analyzing and interpreting data
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Using mathematics and computational thinking
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as , , acre-feet, etc.).
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Constructing explanations (for science) and designing solutions (for engineering)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
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| * Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Constructing explanations (for science) and designing solutions (for engineering)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engaging in argument from evidence
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Obtaining, evaluating, and communicating information
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Tasks of Teaching Science** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| This list includes instructional tasks that teachers engage in that are essential for effective Physics teaching. Many test questions will measure content through application to one or more of these tasks. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Instructional Goals, Big Ideas, and Topics** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting or sequencing appropriate instructional goals or big ideas for a topic
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Identifying the big idea or instructional goal of an instructional activity
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Linking science ideas to one another and to particular activities, models, and representations within and across units
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Investigations and Demonstrations** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting investigations or demonstrations, including virtual, that facilitate understanding of disciplinary core ideas, scientific practices, or crosscutting concepts
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating investigation questions for quality (e.g., testable, empirical)
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Critiquing scientific procedures, data, observations, or results for their quality, accuracy, or appropriateness
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Supporting students in generating questions for investigation or identifying patterns in data and observations
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Resources (texts, curriculum materials, journals, and other print and media-based resources)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating instructional materials and other resources for their ability to address scientific concepts; engage students with relevant phenomena; develop and use scientific ideas; promote students’ thinking about phenomena, experiences, and knowledge; take account of students’ ideas and background; and assess student progress
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Choosing resources that support the selection of accurate, valid, and appropriate goals for science learning
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Student Ideas (including common misconceptions, alternate conceptions, and partial conceptions)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Analyzing student ideas for common misconceptions regarding intended scientific learning**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Selecting diagnostic items and eliciting student thinking about scientific ideas and practices to identify common student misconceptions and the basis for those misconceptions**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Developing or selecting instructional moves, approaches, or representations that provide evidence about common student misconceptions and help students move toward a better understanding of the idea, concept, or practice**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Language, Discourse, Vocabulary, and Definitions** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Selecting scientific language that is precise, accurate, grade-appropriate, and illustrates key scientific concepts**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Anticipating scientific language and vocabulary that may be difficult for students**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Modeling the use of appropriate verbal and written scientific language in critiquing arguments or explanations, in describing observations, or in using evidence to support a claim, etc.**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Supporting and critiquing students’ participation in and use of verbal and written scientific discourse and argumentation**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Explanations (includes claim, evidence, and reasoning)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. **Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence**
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting explanations of natural phenomena that are accurate and accessible to students
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Models and Representations (analogies, metaphors, simulations, illustrations, diagrams, data tables, performances, videos, animations, graphs, and examples)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating student models or representations for evidence of scientific understanding
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Generating or selecting diagnostic questions to evaluate student understanding of specific models or representations
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating student ideas about what makes for good scientific models and representations
 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |