Massachusetts Tests for Educator Licensure® (MTEL®)

FIELD 11: PHYSICS
TEST OBJECTIVES

Subarea	Multiple-Choice	Range of Objectives	Approximate Test Weighting
I.	Nature of Science	01–05	12%
II.	Force and Motion	06–08	14%
III.	Energy, Momentum, and Heat Transfer	09–11	14%
IV.	Electricity and Magnetism	12–15	15%
V.	Waves, Sound, and Light	16–19	14%
VI.	Modern Physics	20–22	11%
			80%
	Open-Response		
VII.	Integration of Knowledge and Understanding	23	**20%**

Effective September 1, 2009

Massachusetts Tests for Educator Licensure® (MTEL®)
Test Objectives
Field 11: Physics

SUBAREAS:

NATURE OF SCIENCE
FORCE AND MOTION
ENERGY, MOMENTUM, AND HEAT TRANSFER
ELECTRICITY AND MAGNETISM
WAVES, SOUND, AND LIGHT
MODERN PHYSICS
INTEGRATION OF KNOWLEDGE AND UNDERSTANDING

NATURE OF SCIENCE [12%]

0001 Understand the nature of scientific inquiry and scientific processes.

For example:

- Demonstrate knowledge of the principles of scientific inquiry and the dynamic nature of science.
- Demonstrate the ability to formulate scientific questions and testable hypotheses.
- Evaluate the validity of an experimental design to collect data and test a hypothesis.
- Identify sources of and strategies for avoiding bias in scientific investigations.

0002 Understand the processes of gathering, organizing, analyzing, and reporting scientific data.

For example:

- Demonstrate knowledge of appropriate methods and procedures for collecting and analyzing data for physics investigations (e.g., dimensional analysis, computer applications).
- Demonstrate knowledge of various methods of representing, organizing, and reporting experimental results.
- Apply measurement concepts (e.g., accuracy, precision, significant figures, scientific notation, unit conversion) to data collection and analysis.
- Demonstrate knowledge of data analysis tools (e.g., linearizing data, statistics, curve fitting, graphical analysis) to analyze and interpret data.
- Demonstrate the ability to draw conclusions and make predictions from empirical data.

0003 Understand scientific tools, instruments, materials, and safety practices used in physics demonstrations and investigations.

For example:

- Demonstrate knowledge of the safe and proper use of materials and equipment (e.g., lasers, voltage sources) used in physics investigations.
- Select appropriate equipment and procedures for specified physics activities.
- Recognize proper methods for storing, maintaining, and disposing of equipment and materials used in physics investigations.
- Demonstrate knowledge of the appropriate protocols for maintaining safety and responding to emergencies in laboratory and field situations.

0004 Understand the historical and contemporary relationships among science, technology, and society.

For example:

- Demonstrate knowledge of scientific theories (e.g., Copernican revolution, quantum theory, inflationary universe/Big Bang theory, relativity theory) and the events and experiments that contributed to their development.
- Recognize the integration and interdependence among scientific disciplines and between science and technology, including related aspects of chemistry, biology, and earth science.
- Identify the risks, ethical concerns, and potential and real benefits associated with scientific research and developing technologies.
- Recognize how societal conditions support or inhibit scientific research and technological advances.
- Demonstrate knowledge of engineering design and technical applications of physics.
- Evaluate the validity and reliability of scientific claims, information, and sources.

0005 Understand the use of mathematics in physics.

For example:

- Identify the equation or relationship that models a physical situation or a set of data.
- Use principles of algebra to interpret, derive, solve, or graph equations commonly used in physics (e.g., linear equations, quadratic equations).
- Use principles of vector algebra to solve problems in physics (e.g., finding components, direction angles, magnitudes, or resultant vectors).
- Use properties of trigonometric functions, exponential functions, and logarithmic functions to model physical situations.
- Use principles of calculus (e.g., limits, derivatives, integrals) to analyze and solve problems in physics.
- Estimate the order of magnitude of a physical quantity.

FORCE AND MOTION [14%]

0006 Understand concepts related to motion in one and two dimensions.

For example:

- Analyze graphs related to distance, displacement, speed, velocity, acceleration, and time.
- Analyze the vector nature of motion in one and two dimensions.
- Solve problems involving distance, displacement, speed, velocity, constant acceleration, and time.

0007 Understand Newton's laws of motion.

For example:

- Analyze characteristics of each of Newton's laws of motion.
- Analyze a free-body diagram representing the forces (e.g., normal, frictional, gravitational, applied) in a given situation.
- Apply the law of universal gravitation.
- Apply Newton's laws to solve problems in one and two dimensions (e.g., projectile motion, inclined planes, coupled masses).

0008 Understand characteristics of uniform circular motion, rotational dynamics, and fluid mechanics.

For example:

- Analyze characteristics (e.g., force, acceleration) of a particle in uniform circular motion.
- Apply the law of gravitation and principles of circular motion to analyze the motion of planets and satellites.
- Analyze problems involving center of mass and static equilibrium.
- Apply concepts related to torque and moment of inertia to solve problems involving rotational motion.
- Analyze problems using principles of fluids mechanics (e.g., density, pressure, Archimedes' principle, Bernoulli's principle).

ENERGY, MOMENTUM, AND HEAT TRANSFER [14%]

0009 Understand the concepts of energy, work, and power and the principle of conservation of energy.

For example:

- Demonstrate knowledge of the interrelationships among work, energy, and power.
- Calculate the work done by a force in various situations.
- Solve problems involving kinetic energy and potential energy.
- Apply the principle of conservation of energy and the work-energy theorem to analyze mechanical systems.
- Determine power, mechanical advantage, and efficiency as they relate to work and energy in devices such as simple machines.

0010 Understand the conservation of linear momentum and angular momentum.

For example:

- Demonstrate knowledge of the relationship between impulse and change in momentum.
- Analyze elastic and inelastic collisions in terms of energy and momentum in one and two dimensions.
- Analyze situations involving conservation of angular momentum, including the vector nature of angular momentum.

0011 Understand heat transfer and the principles of thermodynamics.

For example:

- Demonstrate knowledge of temperature scales and the molecular interpretation of temperature.
- Analyze methods of heat transfer (i.e., conduction, convection, and radiation).
- Analyze problems involving thermal expansion, heat capacity, and phase changes.
- Apply the principle of conservation of energy to thermodynamic processes (e.g., adiabatic, isothermal, isobaric, isochoric, Carnot cycle) involving internal energy changes, work, and heat transfer.
- Demonstrate knowledge of the concept of entropy and its application at both microscopic and macroscopic scales.

ELECTRICITY AND MAGNETISM [15%]

0012 Understand principles of electrostatics.

For example:

- Explain common electrostatic phenomena in terms of electrostatic polarization, electrostatic breakdown, and conservation of electric charge.
- Apply Coulomb's law to determine the magnitude and direction of electrical forces.
- Analyze the electric field intensity and direction for various simple charge distributions.
- Analyze characteristics of electrostatic potential energy and electrostatic potential.
- Recognize the relationships among electrical force, field, potential, and potential energy.

0013 Understand characteristics of electric current and electric circuits.

For example:

- Analyze factors that affect the resistance of a conductor.
- Use Ohm's law to analyze parallel and series circuits.
- Apply Kirchhoff's laws to analyze circuits.
- Analyze circuits and devices in terms of energy use and power dissipation.
- Analyze the characteristics of RC circuits.

0014 Understand magnetic fields and electromagnetic induction.

For example:

- Demonstrate knowledge of the fundamental properties of permanent magnets.
- Analyze factors that affect the magnitude and direction of a magnetic field.
- Determine the magnitude and direction of the magnetic force on a charge.
- Analyze factors that affect the magnitude of an induced electromotive force.
- Determine the direction of an induced current in a conducting loop.

0015 Understand applications of electromagnetism and electronics.

For example:

- Demonstrate knowledge of the synthesis of electricity and magnetism as expressed by Maxwell's equations.
- Demonstrate knowledge of the basic characteristics of AC circuits (e.g., impedance, inductance, reactance).
- Demonstrate knowledge of the use of electromagnetism in technology (e.g., motors, generators, transformers, meters).
- Demonstrate knowledge of the basic function and use of semiconducting devices (e.g., diodes, transistors).

WAVES, SOUND, AND LIGHT [14%]

0016 Understand oscillations, waves, and wave motion.

For example:

- Analyze the dynamics of simple harmonic motion (e.g., pendulum, mass on spring).
- Analyze relationships among displacement, velocity, and acceleration in simple harmonic motion.
- Describe characteristics of longitudinal and transverse waves.
- Determine a wave's velocity, wavelength, or frequency.
- Analyze the superposition and reflection of waves and wave pulses in various situations (e.g., constructive and destructive interference).

0017 Understand the characteristics of sound waves and the basic principles of acoustics.

For example:

- Analyze properties of sound waves (e.g., amplitude, frequency, intensity) and how they relate to the perception of sound.
- Describe factors that affect the propagation of sound in different media.
- Demonstrate knowledge of the Doppler effect.
- Analyze the interference of two sound waves.
- Solve problems involving resonance, harmonics, and overtones in vibrating strings and air columns.

0018 Understand characteristics of electromagnetic waves.

For example:

- Demonstrate knowledge of the relationship among electricity, magnetism, and electromagnetic waves.
- Describe properties of the electromagnetic spectrum.
- Demonstrate knowledge of diffraction and interference in single and multiple slits.
- Analyze applications of the components of the electromagnetic spectrum (e.g., infrared detectors, solar heating, X-ray machines).
- Demonstrate knowledge of polarization.

0019 Understand the principles of lenses and mirrors.

For example:

- Apply Snell's law and the law of reflection to analyze characteristics of the refraction and reflection of light.
- Identify types and describe characteristics of lenses and mirrors.
- Use ray diagrams to analyze the image formation of a lens or mirror.
- Apply the thin-lens equation to solve problems involving lenses and mirrors.
- Describe applications of lenses and mirrors (e.g., telescopes, compound microscopes, eyeglasses).

MODERN PHYSICS [11%]

0020 Understand the atomic nature of matter and the basic principles of special relativity.

For example:

- Demonstrate knowledge of the kinetic theory of matter and its applications (e.g., the equipartition of energy, the specific heat of solids, the gas laws).
- Describe important experiments leading to the atomic theory (e.g., Millikan's oil-drop experiment, Rutherford's alpha scattering).
- Analyze the Bohr model of the atom and its relationship to atomic spectra.
- Demonstrate knowledge of the basic postulates and concepts of the special theory of relativity.

0021 Understand the basic principles of quantum theory.

For example:

- Apply the concept of light quantization in various situations (e.g., blackbody radiation, photoelectric effect, lasers).
- Demonstrate knowledge of the wave nature of matter (e.g., de Broglie wavelengths, Heisenberg uncertainty principle, double-slit experiment).
- Demonstrate knowledge of the Schrödinger wave equation and related concepts (e.g., wave functions, probability, electron spin).
- Describe interactions between matter and energy (e.g., absorption spectra, quantized energy transitions).
- Demonstrate knowledge of the Pauli exclusion principle.
- Describe the four fundamental forces of nature.

0022 Understand the principles of radioactivity and characteristics of nuclear reactions.

For example:

- Interpret notation used to represent elements, ions, isotopes, and subatomic particles.
- Analyze half-life and radioactive decay processes (e.g., alpha, beta, and gamma decay).
- Describe characteristics of fission and fusion reactions.
- Analyze nuclear reactions using the conservation of mass-energy.
- Demonstrate knowledge of applications of nuclear science in medicine and energy production.

INTEGRATION OF KNOWLEDGE AND UNDERSTANDING [20%]

In addition to answering multiple-choice items, candidates will prepare written responses to questions addressing content summarized in the objective below.

0023 Prepare an organized, developed analysis on a topic related to one or more of the following subareas: Nature of Science; Force and Motion; Energy, Momentum, and Heat Transfer; Electricity and Magnetism; Waves, Sound, and Light; and Modern Physics.

(Refer to objectives 0001 through 0022 and associated descriptive statements.)