NEW YORK STATE TEACHER CERTIFICATION EXAMINATIONS™

FIELD 09: PHYSICS
TEST FRAMEWORK

June 2003
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Subarea		Range of Objectives
	Selected-Response	
I.	Foundations of Scientific Inquiry	0001–0005
II.	Mechanics and Thermodynamics	0006–0011
III.	Electricity and Magnetism	0012–0015
IV.	Waves, Sound, and Light	0016–0019
V.	Quantum Theory and the Atom	0020–0023
	Constructed-Response	
VI.	Foundations of Scientific Inquiry: Constructed-Response Assignment	0001–0005

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Foundations of Scientific Inquiry
Mechanics and Thermodynamics
Electricity and Magnetism
Waves, Sound, and Light
Quantum Theory and the Atom
Foundations of Scientific Inquiry: Constructed-Response Assignment

The New York State physics educator has the knowledge and skills necessary to teach effectively in New York State public schools. The physics teacher is a skilled problem solver who understands the historical development of ideas in science and the connections among mathematics, science, and technology. The physics teacher knows how to access, generate, process, and transfer information using appropriate technologies and can apply knowledge and thinking skills of mathematics, science, and technology to address everyday problems and make informed decisions. Most importantly, the physics teacher understands the process of scientific inquiry and applies physics concepts, principles, and theories to pose questions, seek answers, and communicate explanations of natural phenomena.

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SUBAREA I—FOUNDATIONS OF SCIENTIFIC INQUIRY

0001 Understand the historical and contemporary contexts of the study of physics, including the relationships and common themes that connect mathematics, science, and technology and their applications to everyday life.

For example:

- analyzing the role of early civilizations in establishing the foundations of physics (e.g., the law of the lever, hydrostatics, the idea of the atom)
- recognizing key events and analyzing the contributions of individuals in the development of mechanics, electromagnetism, the kinetic theory, atomic theory, radioactivity, quantum theory, and solid state physics
- demonstrating an understanding of current theories of the origin, structure, and composition of the universe
- assessing the societal implications of developments in physics (e.g., heliocentric theory, nuclear technology, the transistor, the laser)
- applying the laws of physics to geological, chemical, biological, and astronomical systems
- analyzing the use of physics, mathematics, and other sciences in the design of a technological solution to a given problem
- analyzing the role of technology in the advancement of scientific knowledge
- evaluating the appropriateness of a variety of software (e.g., spreadsheets, graphing utilities, statistical packages, simulations) and information technologies to model and solve problems in mathematics, science, and technology
- analyzing solutions to everyday-life problems that incorporate knowledge and skills of mathematics, science, and technology

0002 Understand the process of scientific inquiry and the role of observation and experimentation in explaining natural phenomena.

For example:

- analyzing processes by which new scientific knowledge and hypotheses are generated
- analyzing ethical issues related to the process of doing science (e.g., accurately reporting experimental results)
- evaluating the appropriateness of a specified experimental design to test a given physics hypothesis
- recognizing the role of communication among scientists and between scientists and the public in promoting scientific progress

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FIELD 09: PHYSICS
TEST FRAMEWORK

0003 Understand the processes of gathering, organizing, reporting, and interpreting scientific data and apply this understanding in the context of physics investigations.

For example:

- evaluating the appropriateness of a given method or procedure for collecting data for a specified purpose
- selecting an appropriate and effective graphic representation (e.g., graph, table, diagram) for organizing, reporting, and analyzing given experimental data
- applying procedures and criteria for formally reporting experimental procedures and data to the scientific community
- analyzing relationships between factors (e.g., linear, direct, inverse, direct squared, inverse squared) as indicated by experimental data
- coordinating explanations at different levels of scale, points of focus, and degrees of complexity and specificity
- applying statistical techniques to analyze data

0004 Understand principles and procedures of measurement and the safe and proper use of equipment and materials used in physics investigations.

For example:

- evaluating the appropriateness of SI units of measurement, measuring devices, or methods of measurement for given situations
- analyzing likely sources of error in given measurements in physics experiments
- distinguishing between accuracy and precision in scientific measurements
- using significant figures in performing calculations and expressing measurements
- analyzing the principles upon which given laboratory instruments are based (e.g., oscilloscopes, Geiger counters)
- analyzing hazards associated with given laboratory materials (e.g., projectiles, lasers, radioactive materials, heat sources, chemicals)
- applying safety rules regarding electricity and electrical equipment
- applying proper procedures for dealing with accidents and injuries in the physics laboratory

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0005 Understand the use of mathematics (e.g., dimensional analysis, algebra, vector analysis, calculus) and mathematical modeling in physics.

For example:

- using mathematics to derive and solve equations
- applying algebra and geometry to model physical situations
- applying dimensional analysis to solve problems
- applying trigonometric functions and graphing to solve problems (including vector problems)
- using fundamental concepts of calculus to model and solve problems

SUBAREA II—MECHANICS AND THERMODYNAMICS

0006 Understand concepts related to motion in one and two dimensions, and apply this knowledge to solve problems that require the use of algebra, trigonometry, and graphing.

For example:

- applying the terminology, units, and equations used to describe and analyze one- and two-dimensional motion
- solving problems involving distance, displacement, speed, velocity, and constant acceleration
- interpreting information presented in one or more graphic representations related to distance, displacement, speed, velocity, and constant acceleration
- analyzing the movement of freely falling objects near the surface of the earth

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0007 Understand characteristics of forces and methods used to measure force, and solve problems involving forces.

For example:

- identifying and analyzing the characteristics of the fundamental forces of nature
- identifying forces acting in a given situation
- analyzing experimental designs for measuring forces
- applying graphic solutions to solve problems involving the vector nature of force
- determining the resultant of two or more forces algebraically
- applying the concepts of force, pressure, and density
- applying Pascal's principle to analyze fluid statics
- applying Archimedes' principle to problems involving buoyancy and flotation

0008 Understand and apply the laws of motion (including relativity) and conservation of momentum.

For example:

- analyzing the characteristics of each of Newton's laws of motion and giving examples of each
- applying Newton's laws of motion in solving problems
- solving problems involving gravitational and frictional forces
- solving problems involving springs and force constants
- applying the conservation of momentum to analyze and solve problems
- understanding the implications of special relativity for the laws of motion

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

For example:

- analyzing mechanical systems in terms of work, power, and conservation of energy
- using the concept of conservation of energy to solve problems
- solving problems using the work-energy theorem
- determining power and efficiency as they relate to work and energy in a variety of situations
- analyzing energy conversions in everyday-life situations
- analyzing systems in which total energy is conserved but mechanical energy is not conserved

0010 Understand the characteristics of circular motion, simple harmonic motion, and other periodic motion, and solve problems involving these types of motion.

For example:

- applying vector analysis to describe uniform circular motion in radians
- determining the magnitude and direction of the force acting on a particle in uniform circular motion
- applying characteristics of circular motion and gravitational force to analyze planetary motion
- analyzing the relationships among displacement, velocity, and acceleration in simple harmonic motion (e.g., simple pendulum, mass on a spring)
- analyzing energy interactions in oscillating systems
- solving equilibrium problems involving torques
- applying the relationship between torque and angular acceleration to solve problems
- applying the law of conservation of angular momentum to describe phenomena and solve problems
- applying the law of conservation of energy to systems involving rotational motion

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0011 Understand and apply the principles and laws of thermodynamics.

For example:

- analyzing systems in terms of heat energy, internal energy, and work
- applying the first law of thermodynamics to analyze energy conversions in a variety of situations (e.g., ideal gas, electrical circuit, mechanical systems, optical systems, acoustic systems)
- demonstrating an understanding of the second law of thermodynamics and of how the entropy of a system changes in a variety of situations (e.g., an ice cube melting, a gas cooled at constant volume, Carnot cycle)
- analyzing characteristics of temperature and temperature scales
- solving problems involving thermal expansion and thermal contraction of solids, liquids, and ideal gases
- analyzing methods of heat transfer (i.e., conduction, convection, and radiation) in practical situations
- solving problems involving heat capacity, specific heat, heat transfer, heat of fusion, heat of vaporization, and phase changes
- describing thermal properties of matter (e.g., solids, liquids, gases) in terms of molecular theory

SUBAREA III—ELECTRICITY AND MAGNETISM

0012 Understand characteristics and units of electric charge, electric fields, electric potential, and capacitance; and apply principles of static electricity to problems involving Coulomb's law and electric field intensity.

For example:

- analyzing the behavior of an electroscope in given situations (e.g., charging by induction and conduction)
- analyzing common electrostatic phenomena (e.g., static cling, lightning, St. Elmo's fire)
- applying Coulomb's law to determine the forces between charges
- applying principles of electrostatics to determine electric field intensity
- analyzing the vector nature of electric fields and forces
- applying principles of electrostatics to determine electrical potential
- applying the relationship among capacitance, charge, and potential difference

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0013 Understand and analyze characteristics of DC circuits.

For example:

- analyzing a DC circuit in terms of conservation of energy and conservation of charge (i.e., Kirchhoff's laws)
- analyzing the interrelationships among potential difference, resistance, and current
- analyzing factors that affect resistance
- solving problems involving Ohm's law
- describing how to use various meters to measure properties of an electric circuit
- interpreting schematic diagrams of electric circuits
- analyzing work, energy, and power in DC circuits
- describing the properties of conductors, semiconductors, superconductors (e.g., critical temperature, Meissner effect)
- describing the function of a solid state device in an electric circuit

0014 Understand magnets, electromagnets, and magnetic fields; the effects of magnetic fields on moving electric charges; and the applications of electromagnetism.

For example:

- describing magnetic fields as the result of moving electric charges
- applying the domain theory to the magnetization of ferromagnetic materials
- determining the orientation and magnitude of a magnetic field
- determining the magnitude and direction of the force on a charge or charges moving in a magnetic field
- analyzing the behavior of a current-carrying wire in a magnetic field
- analyzing factors that affect the strength of an electromagnet
- analyzing the use of electromagnetism in technology (e.g., motors, generators, meters, magnetic media)

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0015 Understand and apply the principles of electromagnetic induction and AC circuits.

For example:

- analyzing factors that affect the magnitude of an induced electromotive force (EMF)
- applying the appropriate hand rule to determine the direction of an induced current
- analyzing Lenz's law in terms of conservation of energy
- analyzing the functions of transformers and generators
- analyzing an AC circuit, including relationships involving impedance, reactance, and resonance
- describing how AC and DC can be converted from one form to another

SUBAREA IV—WAVES, SOUND, AND LIGHT

0016 Understand the properties and behavior of waves.

For example:

- demonstrating knowledge of how waves transfer energy and momentum
- comparing types (e.g., longitudinal, transverse) and characteristics (e.g., frequency, period, amplitude, wavelength) of waves
- applying the wave properties to determine a wave's velocity, wavelength, or frequency
- analyzing the transmission and absorption of waves
- analyzing the reflection, refraction, dispersion, diffraction, and polarization of waves
- applying the superposition principle to determine characteristics of a resultant wave
- solving problems involving wave phenomena

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0017 Understand and apply knowledge of the characteristics, production, and transmission of sound waves.

For example:

- analyzing the physical nature of sound waves, including intensity and frequency and how they relate to loudness and pitch, respectively
- analyzing factors that affect the speed of sound in different media
- analyzing characteristics of standing waves in musical instruments (e.g., winds, strings, percussion)
- analyzing situations involving resonance, harmonics, and overtones
- analyzing and solving problems involving the Doppler effect

0018 Understand the production and characteristics of electromagnetic waves.

For example:

- analyzing the properties (e.g., energy, frequency, wavelength) of components (e.g., colors of visible light, ultraviolet radiation) of the electromagnetic spectrum
- analyzing color when light is transmitted, absorbed, and reflected
- analyzing variations in energy, frequency, and amplitude in terms of the vibrations of the sources that produce them (e.g., molecules, electrons, nuclear particles)
- analyzing practical applications of the components of the electromagnetic spectrum (e.g., infrared detectors, solar heating, x-ray machines, AM and FM radio signals, holographic images)
- describing how the constancy of the speed of light in a vacuum influences relationships among space, time, and energy
- analyzing and solving problems involving the Doppler effect

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0019 Understand and apply the characteristics of reflective and refractive devices.

For example:

- comparing types and characteristics of lenses and mirrors
- using a ray diagram to locate the focal point or point of image formation of a lens or mirror
- applying the lens and mirror equations to analyze problems involving lenses and mirrors
- applying Snell's law to analyze optical phenomena (e.g., total internal reflection, dispersion)
- analyzing given applications of lenses, mirrors, and prisms (e.g., telescopes, compound microscopes, eyeglasses)

SUBAREA V—QUANTUM THEORY AND THE ATOM

0020 Understand the dual nature of light and matter.

For example:

- describing the quantization of energy in terms of Planck's theory
- applying the laws of photoelectric emission to explain photoelectric phenomena
- applying the principles of stimulated emission of radiation to lasers and masers
- analyzing evidence supporting the dual nature of light and matter
- solving problems using de Broglie's equation
- applying the uncertainty principle in various situations

0021 Understand physical models of atomic structure and the nature of elementary particles.

For example:

- analyzing historic and contemporary models of atomic structure (e.g., Rutherford, Bohr, Schrödinger, Dirac, Heisenberg, Pauli)
- interpreting notation used to represent elements, molecules, ions, and isotopes
- analyzing bright-line spectra in terms of electron transitions
- recognizing the relationship between the design of particle accelerators and elementary particle characteristics

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0022 Understand the standard model of particle physics.

For example:

- recognizing key contributions by individuals (e.g., Gell-Mann, Feynman) in the development of the standard model
- describing historical developments leading to the standard model
- describing experimental techniques and methods used to investigate elementary particles
- describing the families of subnuclear particles (e.g., fermions, bosons, baryons, hadrons) and their properties
- explaining the properties of quarks and how they interact to form protons, neutrons, and other particles
- describing relationships between particles and antiparticles

0023 Understand the principles of radioactivity and nuclear reactions and their applications.

For example:

- applying principles of the conservation of mass number and charge to balance equations for nuclear reactions
- analyzing radioactive decay including the half-life concept and the nuclear disintegration series for a given isotope
- describing the basic operation of types of radiation detectors
- analyzing characteristics of fission and components of a nuclear reactor (e.g., moderator, fuel rods, control rods), including the problems associated with operating a nuclear reactor
- analyzing fusion reactions and their application to the sun's energy and astronomy
- applying the principle of conservation of mass-energy to calculate nuclear mass defect and binding energy

SUBAREA VI—FOUNDATIONS OF SCIENTIFIC INQUIRY: CONSTRUCTED-RESPONSE ASSIGNMENT

The content to be addressed by the constructed-response assignment is described in Subarea I, Objectives 01–05.

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