NEW YORK STATE TEACHER CERTIFICATION EXAMINATIONS™

FIELD 163: PHYSICS

TEST DESIGN AND FRAMEWORK

DRAFT

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This document is a working draft. The information in this document is subject to change, and any changes will fully supersede the information contained in this draft.

NEW YORK STATE TEACHER CERTIFICATION EXAMINATIONS™

FIELD 163: PHYSICS
TEST DESIGN

This test consists of selected-response items measuring content knowledge and one extended constructed-response item measuring pedagogical content knowledge. The constructed-response item is scenario-based and requires candidates to describe an instructional strategy to guide all students in achieving a specific learning goal, assess student understanding, and identify students' strengths and needs.

The selected-response items count for 80% of the total test score and the constructed-response item counts for 20% of the total test score, as indicated in the table that follows. Each selected-response item counts the same toward the total test score. The percentage of the total test score derived from the constructed-response item is also indicated in the table that follows.

The total testing time is 195 minutes. Candidates are free to set their own pace during the test administration. The following estimates were used to determine the total test time:

- The constructed-response item is designed with the expectation of a response time up to 60 minutes.
- The selected-response items are designed with the expectation of a response time up to 135 minutes.

Further information regarding the content of each competency can be found in the test framework.

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Competency		Selected-Response		Constructed-Response	
		Approximate Number of Items	Approximate Percentage of Test Score	Number of Items	Approximate Percentage of Test Score
0001	Forces and Motion	17	16%	--	--
0002	Conservation of Energy and Energy Transfer	17	16%	--	--
0003	Electricity and Magnetism	17	15%	--	--
0004	Mechanical Wave Properties	13	11%	--	--
0005	Optics and Electromagnetic Waves	13	11%	--	--
0006	Modern Physics	13	11%	--	--
0007	Pedagogical Content Knowledge	--	--	1	20%
	Total	**90**	**80%**	**1**	**20%**

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Forces and Motion
Conservation of Energy and Energy Transfer
Electricity and Magnetism
Mechanical Wave Properties
Optics and Electromagnetic Waves
Modern Physics
Pedagogical Content Knowledge

The New York State physics teacher has the knowledge and skills necessary to teach effectively in New York State schools. The physics teacher understands and applies current education research on how students learn physics. The physics teacher demonstrates mastery of the content and concepts of physics, is a skilled problem solver, and demonstrates strong mathematics and literacy skills. The physics teacher applies the three-dimensional approach (i.e., disciplinary core ideas, crosscutting concepts, science and engineering practices) to science instruction in order to explain phenomena, solve real-world problems, and make informed decisions. The physics teacher has a broad understanding of the disciplinary core ideas in physics and the crosscutting concepts between science disciplines. In addition, the physics teacher understands science and engineering practices and applies scientific concepts, principles, and theories to develop and use models; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; and obtain, evaluate, and communicate scientific and technical information from a variety of source types. The physics teacher knows, demonstrates, and implements policies and procedures to ensure laboratory safety and ethical practices.

As used in this document, the term "research-based" refers to those practices that have been shown to be effective in improving learner outcomes through systematic observation or experiment, rigorous data analysis, ability to replicate results, and publication in a peer-reviewed journal.

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COMPETENCY 0001—FORCES AND MOTION

Performance Expectations

The New York State physics teacher understands concepts, reasoning strategies, and model development in the domain of forces and motion. The teacher applies multiple representations to describe and analyze motion in one and two dimensions. The teacher understands the vector nature of force and applies Newton's laws of motion to analyze forces and predict the motion of objects. The teacher makes connections between concepts of force, impulse, and momentum and applies the conservation of momentum in one and two dimensions. The teacher applies kinematic relationships and Newton's laws to systems of particles and analyzes the rotational motion of rigid bodies. The teacher demonstrates knowledge of oscillating systems and the characteristics of simple harmonic motion. The teacher analyzes interactions involving forces, as well as the principles of fluid mechanics. The teacher also demonstrates knowledge of the limitations of Newton's laws. The teacher understands how to plan and safely carry out scientific investigations, understands the process of engineering design in refining a solution to a problem, interprets scientific information, and evaluates specific claims made about scientific phenomena related to forces and motion. In addition, the teacher applies knowledge of the safe and proper use of equipment and materials in school science investigations.

Performance Indicators

a. analyzes and describes motion in one and two dimensions using multiple representations (e.g., graphical, pictorial, mathematical)

b. analyzes and evaluates situations involving projectile motion in one and two dimensions

c. analyzes and describes rotational motion using multiple representations (e.g., graphical, pictorial, mathematical)

d. represents and manipulates vectors to evaluate physical phenomena

e. applies Newton's second law to predict an object's motion

f. analyzes and evaluates situations involving uniform circular motion and centripetal force using multiple representations

g. applies Newton's third law to analyze interactions between objects

h. analyzes and evaluates situations involving impulse and momentum using multiple representations

i. applies the conservation of momentum in one and two dimensions to analyze and evaluate interactions using multiple representations

j. demonstrates knowledge of concepts of torque, angular acceleration, and moment of inertia to model situations and solve problems

k. demonstrates knowledge of the principle of conservation of angular momentum to rotating bodies

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l. analyzes systems undergoing simple harmonic motion (e.g., pendulum, mass on a spring)

m. analyzes and evaluates systems in static equilibrium

n. analyzes and evaluates situations involving Hooke's law using multiple representations

o. analyzes and evaluates situations involving frictional forces using multiple representations

p. demonstrates knowledge of principles of fluid mechanics (e.g., density, pressure, Archimedes's principle, Bernoulli's principle)

q. analyzes and evaluates situations involving universal gravitation including problems involving satellite and planetary motion

r. demonstrates knowledge of functional limitations of Newton's laws at high speeds and subatomic scales

s. demonstrates knowledge of the conceptual foundation and historical origins of scientific models of force and motion

t. demonstrates knowledge of the engineering design process as related to forces and motion, including criteria, modeling, use of technology and mathematical thinking, and applications to real-world situations; and evaluates an engineering design or solution, taking into account a range of constraints, including cost, safety, reliability, and aesthetics, and considering social, cultural, and environmental impacts

u. demonstrates knowledge of how to plan, construct, and safely and ethically carry out investigations into forces and motion (e.g., constructing a bottle rocket and analyzing its launch and flight, examining the forces on and acceleration of an object with masses attached to it)

v. analyzes and draws inferences from experimental data, scientific and technical texts, and graphics; interprets graphs and data; applies mathematical and computational thinking in analyzing data; and evaluates the hypotheses, data, analyses, and conclusions in a scientific or technical text related to forces and motion

w. demonstrates knowledge of appropriate resources regarding the safe and proper use of scientific equipment and materials (e.g., inventory, handling, storage, disposal), including accurately interpreting provided information; applies knowledge of guidelines for the proper use of materials and scientific equipment in field, laboratory, and classroom settings; and understands proper procedures for maintaining safety and responding to accidents and injuries during school science investigations

COMPETENCY 0002—CONSERVATION OF ENERGY AND ENERGY TRANSFER

Performance Expectations

The New York State physics teacher understand concepts, reasoning strategies, and model development in the domain of conservation of energy and energy transfer. The teacher applies the concepts of force and displacement to analyze situations involving work and energy. The teacher applies knowledge of kinetic and potential energy and analyzes the potential energy for a variety of forces. The teacher applies knowledge of the conservation of energy and analyzes phenomena using the first and second laws of thermodynamics. In addition, the teacher understands how to plan and safely carry out scientific investigations, understands the process of engineering design in refining a solution to a problem, interprets scientific information, and evaluates specific claims made about scientific phenomena related to the conservation of energy and energy transfer.

Performance Indicators

a. describes and explains a variety of physical phenomena in terms of energy transformations and conservation

b. analyzes and evaluates situations involving work, energy, and power, including energy flow and conservation, using multiple representations

c. analyzes and evaluates situations involving the relationships between force, distance, work, kinetic energy, and potential energy

d. demonstrates understanding of conservative and nonconservative forces and fields

e. solves engineering, graphical, and mathematical problems using the work-energy theorem

f. analyzes, evaluates, and predicts the outcome of collisions in terms of energy

g. demonstrates knowledge of the mechanical equivalence of heat, thermodynamic work, and internal energy (e.g., *PV* diagrams, friction, heat engines)

h. demonstrates knowledge of the first and second laws of thermodynamics to analyze energy transformations

i. describes states of matter and phase changes in terms of molecular interactions

j. demonstrates knowledge of the conceptual foundation and historical origins of scientific models of energy

k. demonstrates knowledge of the engineering design process as related to the conservation of energy and energy transfer, including criteria, modeling, use of technology and mathematical thinking, and applications to real-world situations; and evaluates an engineering design or solution, taking into account a range of constraints, including cost, safety, reliability, and aesthetics, and considering social, cultural, and environmental impacts

l. demonstrates knowledge of how to plan, construct, and safely and ethically carry out investigations into conservation of energy and energy transfer (e.g., developing and analyzing an efficient way to lift an object, building a heat engine and quantifying the work it can do)

m. analyzes and draws inferences from experimental data, scientific and technical texts, and graphics; interprets graphs and data; applies mathematical and computational thinking in analyzing data; and evaluates the hypotheses, data, analyses, and conclusions in a scientific or technical text related to the conservation of energy and energy transfer

COMPETENCY 0003—ELECTRICITY AND MAGNETISM

Performance Expectations

The New York State physics teacher understands concepts, reasoning strategies, and model development in the domain of electricity and magnetism. The teacher applies knowledge of electric and magnetic interactions and fields to analyze electromagnetic phenomena. The teacher has a deep conceptual understanding of the concept of an electric circuit and applies this knowledge to analyze a variety of circuits and devices. The teacher makes connections between concepts of energy, work, and power and electric and magnetic phenomena. In addition, the teacher understands how to plan and safely carry out scientific investigations, understands the process of engineering design in refining a solution to a problem, interprets scientific information, and evaluates specific claims made about scientific phenomena related to electricity and magnetism.

Performance Indicators

a. analyzes and evaluates situations involving Coulomb's law using multiple representations

b. analyzes and evaluates situations involving magnets using multiple representations

c. applies the concept of an electric field and analyzes the electric field for discrete charge distributions

d. demonstrates knowledge of the magnetic field and analyzes the magnetic field for simple current distributions, including the direction of current

e. analyzes connections between electric fields and concepts of work, potential energy, and potential difference

f. demonstrates knowledge of how electric and magnetic fields affect the flow of energy and energy storage

g. demonstrates conceptual knowledge of a complete circuit, current, and voltage

h. analyzes and evaluates DC circuits using a variety of strategies (i.e., Ohm's law, Kirchhoff's laws)

i. analyzes and evaluates circuits involving different combinations of resistors, inductors, and/or capacitors using a variety of strategies

j. demonstrates knowledge of connections between alternating current circuits and electromagnetic waves

k. analyzes and evaluates electric circuits and devices in terms of energy and power, including designing solutions for authentic situations

l. demonstrates knowledge of Faraday's and Lenz's laws in situations (e.g., generators, transformers, motors) involving changing magnetic fields, induced currents, and electromotive forces

m. analyzes the motion of charged particles in electric and magnetic fields to predict their direction and pathways

n. demonstrates knowledge of the conceptual foundation and historical origins of scientific models of electricity and magnetism

o. demonstrates knowledge of the engineering design process as related to electricity and magnetism, including criteria, modeling, use of technology and mathematical thinking, and applications to real-world situations; and evaluates an engineering design or solution, taking into account a range of constraints, including cost, safety, reliability, and aesthetics, and considering social, cultural, and environmental impacts

p. demonstrates knowledge of how to plan, construct, and safely and ethically carry out investigations into electricity and magnetism (e.g., using a computer-based simulation to explore the electric field around charged objects, investigating the current produced from moving a magnet through loops of copper wire)

q. analyzes and draws inferences from experimental data, scientific and technical texts, and graphics; interprets graphs and data; applies mathematical and computational thinking in analyzing data; and evaluates the hypotheses, data, analyses, and conclusions in a scientific or technical text related to electricity and magnetism

COMPETENCY 0004—MECHANICAL WAVE PROPERTIES

Performance Expectations

The New York State physics teacher understands concepts, reasoning strategies, and model development in the domain of mechanical wave properties. The teacher demonstrates knowledge of how waves transmit energy and momentum through a medium. The teacher analyzes a variety of wave properties and their applications. The teacher understands concepts associated with sound, harmonics, and resonance. In addition, the teacher understands how to plan and safely carry out scientific investigations, understands the process of engineering design in refining a solution to a problem, interprets scientific information, and evaluates specific claims made about scientific phenomena related to mechanical wave properties.

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Performance Indicators

a. demonstrates knowledge of mechanical wave properties, including propagation and speed, and what constitutes a wave

b. analyzes and evaluates wave phenomena in terms of amplitude, wave speed, phase, and wavelength to solve conceptual, engineering, graphical, and mathematical problems using multiple representations

c. analyzes and evaluates wave reflection, absorption, and transmission (e.g., refraction) at a boundary between media using multiple representations

d. analyzes and evaluates wave interactions using the superposition principle

e. demonstrates knowledge of wave interference and diffraction

f. analyzes and evaluates patterns and characteristics of standing waves (e.g., harmonics, resonance) using multiple representations

g. demonstrates knowledge of the Doppler effect, including real-world applications

h. demonstrates knowledge of the conceptual foundation and historical origins of scientific models of waves

i. demonstrates knowledge of the engineering design process as related to mechanical wave properties, including criteria, modeling, use of technology and mathematical thinking, and applications to real-world situations; and evaluates an engineering design or solution, taking into account a range of constraints, including cost, safety, reliability, and aesthetics, and considering social, cultural, and environmental impacts

j. demonstrates knowledge of how to plan, construct, and safely and ethically carry out investigations into properties of waves (e.g., investigating the properties of standing waves with an oscillator and string, using computer-based software to record observed changes in sound frequency of moving objects)

k. analyzes and draws inferences from experimental data, scientific and technical texts and graphics; interprets graphs and data; applies mathematical and computational thinking in analyzing data; and evaluates the hypotheses, data, analyses, and conclusions in a scientific or technical text related to the properties of waves

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COMPETENCY 0005—OPTICS AND ELECTROMAGNETIC WAVES

Performance Expectations

The New York State physics teacher understands concepts, reasoning strategies, and model development in the domain of optics and electromagnetic waves. The teacher applies the ray approximation to analyze characteristics of shadows, lenses, and mirrors. The teacher demonstrates knowledge of the source of electromagnetic radiation and interprets the electromagnetic spectrum in terms of frequency and wavelength. The teacher understands wave properties of interference, diffraction, and polarization and their applications to optics. In addition, the teacher understands how to plan and safely carry out scientific investigations, understands the process of engineering design in refining a solution to a problem, interprets scientific information, and evaluates specific claims made about scientific phenomena related to optics and electromagnetic waves.

Performance Indicators

a. demonstrates knowledge of properties of light including propagation and speed

b. analyzes the behavior of light in the presence of opaque objects using ray diagrams

c. analyzes the behavior of light in mirrors and lenses using multiple representations

d. analyzes wave refraction using multiple representations

e. demonstrates knowledge of the production and transmission of electromagnetic radiation

f. understands characteristics of the electromagnetic spectrum (e.g., radio, infrared, visible light, X-rays)

g. applies knowledge of wave properties to electromagnetic radiation (e.g., Doppler effect, polarization)

h. demonstrates knowledge of wave interference and diffraction, including diffraction patterns formed by single- and double-slit interference

i. demonstrates knowledge of how instruments (e.g., wireless networks, medical imaging devices) transmit and detect information

j. demonstrates knowledge of the conceptual foundation and historical origins of scientific models of optics and electromagnetic waves

k. demonstrates knowledge of the engineering design process as related to optics and electromagnetic waves, including criteria, modeling, use of technology and mathematical thinking, and applications to real-world situations; and evaluates an engineering design or solution, taking into account a range of constraints, including cost, safety, reliability, and aesthetics, and considering social, cultural, and environmental impacts

l. demonstrates knowledge of how to plan, construct, and safely and ethically carry out investigations into optics and electromagnetic waves (e.g., investigating images formed by various optical instruments, investigating wireless radio signals using a variety of electronic equipment)

m. analyzes and draws inferences from experimental data, scientific and technical texts, and graphics; interprets graphs and data; applies mathematical and computational thinking in analyzing data; and evaluates the hypotheses, data, analyses, and conclusions in a scientific or technical text related to optics and electromagnetic waves

COMPETENCY 0006—MODERN PHYSICS

Performance Expectations

The New York State Physics teacher understands concepts, reasoning strategies, and model development in the domain of modern physics. The teacher understands current models of the atom, the structure of matter, the dual nature of light, and the history of the development of these concepts. The teacher demonstrates knowledge of nuclear processes and the conservation of mass-energy. The teacher demonstrates knowledge of basic principles of quantum mechanics, special relativity, and the Standard Model. In addition, the teacher understands how to plan and safely carry out scientific investigations, understands the process of engineering design in refining a solution to a problem, interprets scientific information, and evaluates specific claims made about scientific phenomena related to modern physics.

Performance Indicators

a. demonstrates knowledge of the structure of the atom and characteristics of the electromagnetic, strong, and weak interactions in atoms and nuclei

b. demonstrates knowledge of electron transitions, associated energy diagrams, and applications (e.g., flame test, LEDs)

c. demonstrates knowledge of the observations and reasoning necessitating the particulate nature of light

d. analyzes and evaluates situations involving the photoelectric effect

e. demonstrates knowledge of nuclear radiation, half-life, radioisotopes, and nuclear reactions, as well as their applications

f. demonstrates knowledge of nuclear fission, nuclear fusion, and mass-energy equivalence

g. demonstrates knowledge of basic principles of quantum mechanics (e.g., wave–particle duality, probability amplitudes, uncertainty principle)

h. demonstrates knowledge of the fundamental principles of special relativity (e.g., time dilation, length contraction)

i. describes experimental techniques and methods used to investigate elementary particles and the fundamental ideas related to the Standard Model

j. demonstrates knowledge of the conceptual foundation and historical origins of the key ideas of modern physics

k. demonstrates knowledge of the engineering design process as related to modern physics, including criteria, modeling, use of technology and mathematical thinking, and applications to real-world situations; and evaluates an engineering design or solution, taking into account a range of constraints, including cost, safety, reliability, and aesthetics, and considering social, cultural, and environmental impacts

l. demonstrates knowledge of how to plan, construct, and safely and ethically carry out investigations into the structure and properties of matter and nuclear processes (e.g., using a computer simulation to investigate nuclear radiation and nuclear reactions, investigating the wavelengths of light that can eject electrons from various metallic surfaces)

m. analyzes and draws inferences from experimental data, scientific and technical texts, and graphics; interprets graphs and data; applies mathematical and computational thinking in analyzing data; and evaluates the hypotheses, data, analyses, and conclusions in a scientific or technical text related to modern physics

COMPETENCY 0007—PEDAGOGICAL CONTENT KNOWLEDGE

<u>Performance Expectations</u>

The New York State physics teacher effectively applies pedagogical content knowledge to design culturally relevant instruction to guide all students in achieving a specific learning goal using an effective three-dimensional approach (i.e., disciplinary core idea, crosscutting concept, science or engineering practice). The teacher also applies knowledge of current education research on how students learn science in order to develop safe and effective performance tasks that will guide all students, including diverse learners, in achieving a specific learning goal. The teacher appropriately assesses student knowledge and understanding and identifies potential and apparent student strengths and needs.

<u>Performance Indicators</u>

a. demonstrates knowledge of how to assess student readiness for a specific new learning goal related to a physics concept or science or engineering practice

b. applies knowledge of how to design culturally relevant instruction using appropriate and effective instructional strategies that connect students' prior understanding and real-world experiences to new knowledge for all students, including diverse learners

c. applies knowledge of how to design appropriate and effective three-dimensional instruction (i.e., disciplinary core ideas, crosscutting concepts, science or engineering practices) to support students in applying and developing understanding of physics concepts

d. applies knowledge of appropriate and effective research-based strategies to guide all students to engage safely in physics concepts or science and engineering practices

e. applies knowledge of appropriate and effective assessment to evaluate and promote learning and growth for all students, including diverse learners