



ARIZONA EDUCATOR PROFICIENCY ASSESSMENTS™



STUDY GUIDE

09 Physics

This AEPA test was replaced by a NES test. Examinees may continue to find this study guide useful as they prepare for the NES, as the previous AEPA test may have covered objectives and content similar to the NES test.

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TABLE OF CONTENTS

Field 09: Physics

PART 1: GENERAL INFORMATION ABOUT THE AEPA AND TEST PREPARATION

AN OVERVIEW OF THE AEPA.....	1-1
Test Development Process	
Characteristics of the AEPA	
Test Administration	
How AEPA Test Scores Are Computed and Reported	
HOW TO PREPARE FOR THE TESTS	1-3
Study the Test Objectives	
Focus Your Studies	
Identify Resources	
Develop Study Techniques	
Answer the Practice Questions	
Review the Sample Answer Sheet and Written Response Booklet	
Test Directions	
Sample Answer Sheet	
Sample Written Response Booklet	
WHAT TO EXPECT THE DAY OF THE TEST	1-12
The Morning of the Administration	
At the Test Site	
SAMPLE TEST OBJECTIVES AND QUESTIONS	1-13
Organization of the Test Objectives	
Question Formats and Strategies	
Selected-Response-Question Formats	
Performance Assignment Formats	
Evaluation of the Sample Written Performance Assignment Response	

PART 2: FIELD-SPECIFIC INFORMATION

INTRODUCTION	2-1
TEST OBJECTIVES	2-2
PRACTICE QUESTIONS	2-7
ANSWER KEY	2-24

STUDY GUIDE ORDER FORM



PART 1: GENERAL INFORMATION ABOUT THE AEPA™ AND TEST PREPARATION

Part 1 of this study guide is contained in a separate PDF file. Click the link below to view or print this section:

[General Information About the AEPA and Test Preparation](#)



PART 2: FIELD-SPECIFIC INFORMATION

Field 09: Physics

INTRODUCTION

This section includes a list of the test objectives, practice questions, and an answer key for the selected-response questions.

Test objectives. As noted earlier, the test objectives are broad, conceptual statements that reflect the knowledge, skills, and understanding an entry-level educator needs to practice effectively in Arizona schools. The list of test objectives for each test field is the *only* source of information about what a specific test will cover and therefore should be studied carefully.

Practice questions. The practice selected-response questions and practice performance assignments included in this section are designed to give you an introduction to the nature of the questions included in the AEPA tests. The practice questions represent the various types of questions you may expect to see on an actual test; however, they are *not* designed to provide diagnostic information to help you identify specific areas of individual strengths and weaknesses or to predict your performance on the test as a whole.

When you answer the practice questions, you may wish to use the sample answer sheet and sample Written Response Booklet provided in Part 1 to acquaint yourself with these materials. Use the answer key located after the practice questions to check your answers. Sample responses are provided immediately following each written performance assignment. The sample responses in this guide are for illustrative purposes only. Your written response should be your original work, written in your own words, and not copied or paraphrased from some other work.

To help you identify how the test objectives are measured, the objective statement to which the question corresponds is listed in the answer key. When you are finished with the practice questions, you may wish to go back and review the entire list of test objectives and descriptive statements for your test field.

TEST OBJECTIVES

Field 09: Physics

SUBAREAS:

1. Scientific Inquiry
2. Mechanics and Heat Energy
3. Electricity and Magnetism
4. Waves, Sound, and Light
5. Quantum Theory and the Atom

SCIENTIFIC INQUIRY

0001 Understand the historical and contemporary contexts of the study of physics.

For example: the significance of key events, theories, and individuals in the history of physics; the historical development of theories and knowledge in physics; the social contexts of physics; and the societal implications of developments in physics (e.g., nuclear technology, semi-conductors, superconductors).

0002 Understand the nature of science and scientific inquiry.

For example: processes by which new scientific knowledge and hypotheses are generated; processes by which science advances; the reliance of science on empirical data, verifiable evidence, and logical reasoning; ethical issues related to scientific processes (e.g., accurately reporting experimental results); and the role of communication among scientists and between scientists and the public in promoting scientific progress.

0003 Understand principles and procedures of classroom physics investigations.

For example: the identification of questions that can be answered using scientific methods; procedures and considerations in setting up and conducting a physics laboratory investigation; the use of microcomputer-based laboratory equipment (MBL) to collect and analyze data; the use of control and experimental groups to test hypotheses; the appropriateness of a specified experimental design to test a given physics hypothesis; and the selection and use of materials and techniques for physics investigations.

0004 Understand the processes of gathering, organizing, reporting, and analyzing scientific data in the context of physics investigations.

For example: the appropriateness of a given method or procedure for collecting data for a specified purpose; the design and use of models; applications of statistics (e.g., linear regression models, correlation coefficients, percent deviation between experimental and accepted values); appropriate and effective graphic representations (e.g., graph, table, diagram) for organizing and reporting experimental data; procedures and criteria for formally reporting experimental procedures and data to the scientific community; and relationships between factors (e.g., linear, direct, inverse, direct squared, inverse squared) as indicated by experimental data.

0005 Understand the interrelationships among physics, society, technology, and other sciences and disciplines.

For example: unifying concepts and processes among the sciences; the effects of physics and technology on one another and on society; similarities and differences between science and technology (e.g., science as investigating the natural world, technology as solving human adaptation problems); ethical considerations related to science and technology; and the application of physics to other disciplines and to daily life.

MECHANICS AND HEAT ENERGY

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: the terminology, units, and equations used to describe and analyze one- and two-dimensional motion; the difference between instantaneous and average velocity; the movement of freely falling objects near the surface of the earth; solving problems involving distance, displacement, speed, velocity, and constant acceleration; and analyzing interrelationships among displacement-versus-time, velocity-versus-time, and acceleration-versus-time graphs.

0007 Understand the vector nature of forces and methods used to measure force; and solve conceptual, graphical, and algebraic problems involving forces.

For example: identifying forces acting in a given situation; finding the resultant force using graphical and trigonometric methods; experimental designs for measuring forces; solving problems involving gravitational and frictional forces; and solving problems involving static equilibrium.

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

For example: the characteristics and examples of each of Newton's laws of motion; applying Newton's laws of motion and the conservation of momentum in solving problems; and the implications of special relativity for the laws of motion.

0009 Understand the characteristics of circular motion and simple harmonic motion, and solve problems involving these types of motion.

For example: applying vector analysis to describe uniform circular motion; determining the magnitude and direction of the force acting on a particle in uniform circular motion; the relationships among displacement, velocity, and acceleration in simple harmonic motion (e.g., simple pendulum); and solving problems involving mass-spring systems.

0010 Understand the law of universal gravitation, and apply it to satellite motion.

For example: the geometric characteristics of planetary orbits; using the law of universal gravitation to interpret the relationship among force, mass, and the distance between masses; and applying the law of universal gravitation to analyze satellite motion.

0011 Understand 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; applying the concept of conservation of energy to solve problems; and determining power and efficiency as they relate to work and energy in operations such as simple machines.

0012 Understand the dynamics of rotational motion, including torque, angular momentum, motion with constant angular acceleration, rotational kinetic energy, center of mass, and moment of inertia.

For example: the principles of motion with constant angular acceleration; the law of conservation of angular momentum; and the concepts of center of mass, moment of inertia, and rotational kinetic energy.

0013 Understand the statics and dynamics of fluids.

For example: the concepts of force, pressure, and density; using Bernoulli's principle to analyze fluid dynamics; and applying Archimedes' principle to solve problems involving buoyancy and flotation.

0014 Understand the principles of the first and second laws of thermodynamics, the relationship between temperature and heat, and the principles of thermal expansion, thermal contraction, and heat transfer.

For example: solving calorimetry problems involving heat capacity, specific heat, heat of fusion, and heat of vaporization; analyzing methods of heat transfer (i.e., conduction, convection, radiation) in practical situations; solving problems involving thermal expansion and thermal contraction of solids; analyzing the relationship among heat, work, and internal energy; and using the principle of entropy to analyze energy conversions.

0015 Understand the kinetic-molecular theory and its relationship to thermodynamics and the characteristics of solids, liquids, and gases.

For example: analyzing the behavior of a gas in terms of the kinetic-molecular theory (i.e., ideal gas law, temperature and kinetic energy); and analyzing phase changes in terms of kinetic-molecular theory and molecular structure.

ELECTRICITY AND MAGNETISM**0016 Understand characteristics and units of electric charge, electric fields, electric potential, and capacitance; and apply principles of static electricity to solve problems involving Coulomb's law and electric fields.**

For example: analyzing the behavior of an electroscope in given situations; applying Coulomb's law to determine the forces between charges; applying principles of electrostatics to determine electric field intensity; and the relationships between capacitance, charge, and potential difference.

0017 Understand characteristics of electric current and components of electric circuits.

For example: analyzing DC circuits (both with and without capacitors) in terms of conservation of energy and conservation of charge (i.e., Kirchhoff's laws, Ohm's law); factors that affect resistance; schematic diagrams of electric circuits; and applying principles of DC circuits to reduce a complex circuit to a simpler equivalent circuit.

0018 Understand the force on a charge in a magnetic field, and understand magnets, magnetic fields, and electromagnets.

For example: the magnitude and direction of the force on a charge or charges moving in a magnetic field; factors that affect the strength of an electromagnet; the orientation and magnitude of a magnetic field; and the use of electromagnetism in technology (e.g., motors, generators, meters).

0019 Understand and apply the principles of electromagnetic induction and AC circuits.

For example: determining the direction of an induced current; factors that affect the magnitude of an induced electromotive force (EMF); analyzing an AC circuit, including relationships involving impedance and reactance; and the functions of transformers and generators.

WAVES, SOUND, AND LIGHT**0020 Understand waves, wave motion, and wave interference.**

For example: types (e.g., longitudinal, transverse) and characteristics (e.g., frequency, period, amplitude, wavelength) of waves; understand the relationship among a wave's velocity, wavelength, and frequency; and apply the superposition principle to solve problems involving constructive and destructive interference.

0021 Understand the characteristics of sound waves and the means by which sound waves are produced and transmitted.

For example: the physical nature of sound waves (including intensity and intensity level); factors that affect the speed of sound in different media; solving problems involving resonance, harmonics, and overtones; and the Doppler effect.

0022 Understand the production and characteristics of electromagnetic waves.

For example: the properties (e.g., energy, frequency, wavelength) of components of the electromagnetic spectrum (e.g., visible light, ultraviolet radiation); applications of the components of the electromagnetic spectrum (e.g., infrared detectors, solar heating, x-ray machines); and using wave properties to explain interference in single and multiple slits and thin films.

0023 Understand the principles of reflection and refraction.

For example: applying Snell's law to determine the index of refraction, angle of incidence, angle of refraction, and the critical angle; 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 solve problems involving lenses and mirrors; and applications of lenses and mirrors (e.g., telescopes, compound microscopes, eyeglasses).

QUANTUM THEORY AND THE ATOM**0024 Understand the principles and concepts of the photoelectric effect, quantum theory, and the wave and particle nature of light and matter.**

For example: applying the laws of photoelectric emission to explain photoelectric phenomena; analyzing bright-line spectra in terms of electron transitions; and the principles of stimulated emission of radiation as applied to lasers.

0025 Understand physical models of atomic structure and the nature of elementary particles.

For example: historic and contemporary models of atomic structure (e.g., Bohr, Schrödinger, Heisenberg, Mayer, Bhabha); notation used to represent elements, molecules, ions, and isotopes; and the use of particle accelerators to explore elementary particle characteristics.

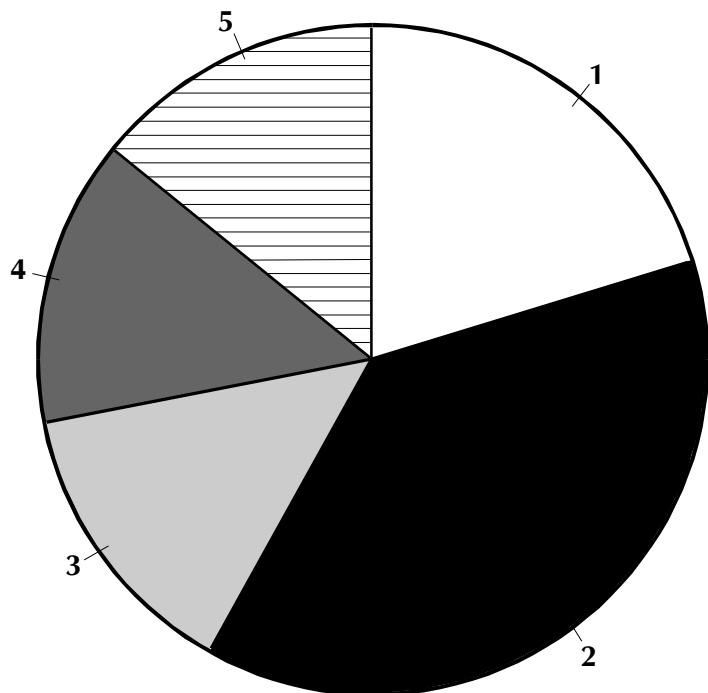
0026 Understand the principles of radioactivity, the types and characteristics of radiation, and the process of radioactive decay.

For example: applying principles of the conservation of mass-energy and charge to balance equations for nuclear reactions; analyzing radioactive decay in terms of the half-life concept; analyzing the nuclear disintegration series for a given isotope; and the basic operation of types of radiation detectors.

0027 Understand types and characteristics of nuclear reactions, methods of initiating and controlling them, and applications of nuclear reactions to the generation of electricity.

For example: characteristics of fission and fusion reactions; the operation of components of a nuclear reactor (e.g., moderator, fuel rods, control rods); calculating nuclear mass defect and binding energy; the isotopes commonly used to fuel nuclear reactors; and the problems associated with the waste products generated by nuclear reactions.

DISTRIBUTION OF SELECTED-RESPONSE ITEMS ON THE TEST FORM



Approximate Percentage
of Selected-Response
Items on Test Form

Subarea	Approximate Percentage of Selected-Response Items on Test Form
1. Scientific Inquiry	19%
2. Mechanics and Heat Energy	36%
3. Electricity and Magnetism	15%
4. Waves, Sound, and Light	15%
5. Quantum Theory and the Atom	15%

PRACTICE QUESTIONS

Field 09: Physics

All examinees taking the Physics test (Field 09) will be provided with a Texas Instruments TI 30X Solar Scientific calculator with functions that include the following: addition, subtraction, multiplication, division, square root, percent, sine, cosine, tangent, exponents, and logarithms. **You may NOT bring your own calculator to the test.**

CONSTANTS

Description	Value
Acceleration of gravity on Earth (g)	9.8 m/s^2
Speed of light in a vacuum (c)	$3.00 \times 10^8 \text{ m/s}$
Planck's constant (h)	$6.63 \times 10^{-34} \text{ J}\cdot\text{s} = 4.14 \times 10^{-15} \text{ eV}\cdot\text{s}$
Electron rest mass	$9.11 \times 10^{-31} \text{ kg}$
Proton rest mass	$1.67 \times 10^{-27} \text{ kg}$
Charge of electron	$-1.60 \times 10^{-19} \text{ C}$
Coulomb's constant (k_e)	$9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$
Boltzmann's constant (k)	$1.38 \times 10^{-23} \text{ J/K}$
Gas constant (R)	$8.31 \text{ J/mol}\cdot\text{K}$
Gravitational constant (G)	$6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
Permeability of free space (μ_0)	$4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$
Avogadro's number	$6.02 \times 10^{23} \text{ particles/mole}$

FORMULAS

Description	Formula
Constant acceleration	$v = v_i + at$ $x = x_i + v_i t + \frac{1}{2} a t^2$ $v_f^2 - v_i^2 = 2a(x_f - x_i)$
Circular motion	$a = \frac{v^2}{r}$ $\theta = \theta_i + \omega_i t + \frac{1}{2} \alpha t^2$ $\omega = \omega_i + \alpha t$ $v = r\omega$ $a = r\alpha$ $\tau = I\alpha$
Spring	$F = -kx$ $PE = \frac{1}{2} kx^2$ $T = 2\pi\sqrt{\frac{m}{k}}$
Pendulum	$T = 2\pi\sqrt{\frac{L}{g}}$
Relativity	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
Speed of sound in an ideal gas	$v = \sqrt{\frac{\gamma RT}{M}}$
Speed of waves in a string	$v = \sqrt{\frac{T}{\mu}}$
Standing wave condition for a string fixed at both ends	$2L = n\lambda, n \text{ is an integer}$
Standing wave condition for a string fixed at one end	$4L = n\lambda, n \text{ is odd}$
Optics	$n_1 \sin \theta_1 = n_2 \sin \theta_2$ $n = \frac{c}{v}$ $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$

FORMULAS (continued)

Description	Formula
Thermodynamics	$\Delta U = nC_v \Delta T$ $\Delta Q = mc \Delta T$ $PV = nRT$ $\frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT$
Fluids	$p = \rho gh$
Magnetism	$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ $\mathbf{F} = I\ell \times \mathbf{B}$ $\oint \mathbf{B} \cdot d\ell = \mu_0 I$ $\mathcal{E}_{\text{ave}} = -\frac{\Delta\phi}{\Delta t}$ $\phi = B_{\perp}A$
Alternating circuit	$\mathcal{E} = -L \frac{dI}{dt}$ $\omega_0 = \frac{1}{\sqrt{LC}}$ $X_L = \omega L$ $X_C = \frac{1}{\omega C}$ $Z = \sqrt{(X_C - X_L)^2 + R^2}$
Photoelectric effect	$hf = \phi + eV_s$
Wave-particle relations	$E = hf$ $h = p\lambda$

NOTES FOR PHYSICS TEST

Not all formulas necessary are listed, nor are all formulas listed used on this test.

In questions on electricity and magnetism, the term *current* refers to "conventional current" and the use of the right-hand rule is assumed.

While attention has been paid to significant figures, no answer should be considered incorrect solely because of the number of significant figures.

1. Use the description of an experiment below to answer the question that follows.

Tape a pencil to the edge of a table so that half of the pencil is hanging over the edge. Hang a rubber band on the pencil and attach a paper clip to the bottom of the rubber band. Measure the initial length of the rubber band. Attach a washer to the paper clip and measure the length of the band. Repeat with 2, 3, 4, and 5 identical washers. Graph your results.

Which of the following is the independent variable in the experiment above?

- A. the initial length of the rubber band
- B. the length of the rubber band after each washer is added
- C. the number of washers attached to the paper clip
- D. the mass of a single washer

2. Use the table below to answer the question that follows.

	Gun A	Gun B
Mean Distance	141.3 cm	138.5 cm
Standard Deviation	2.4 cm	3.1 cm

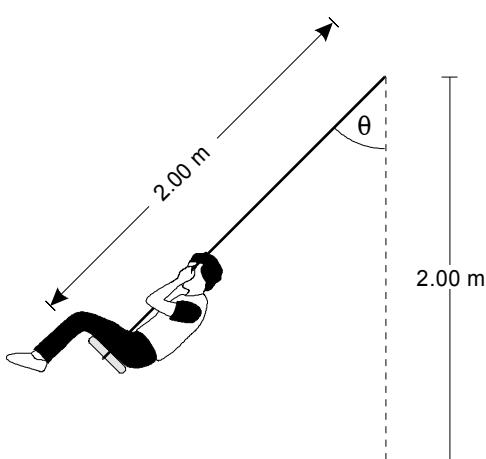
The table gives data on the horizontal distance traveled by a ball fired from two different spring guns under identical conditions. Which of the following statements best describes the data?

- A. The data collected for Gun A are more precise than the data collected for Gun B.
- B. The data collected for Gun A are more accurate than the data collected for Gun B.
- C. The data collected for Gun A show a greater random error than the data collected for Gun B.
- D. The data collected for Gun A show a greater amount of experimental design error than the data collected for Gun B.

3. A rocket 15.0 m long passes through a tunnel that is 12.0 m long and at rest relative to the rocket. How fast does the rocket have to travel in order to just fit inside the tunnel when it passes through?

A. $0.10c$
B. $0.60c$
C. $0.80c$
D. $1.67c$

4. Use the diagram below to answer the question that follows.



The length of the ropes on a playground swing is 2.00 m. What is the maximum speed attainable on the swing if the maximum value of θ is 45° ?

A. 1.41 m/s
B. 2.00 m/s
C. 3.39 m/s
D. 8.85 m/s

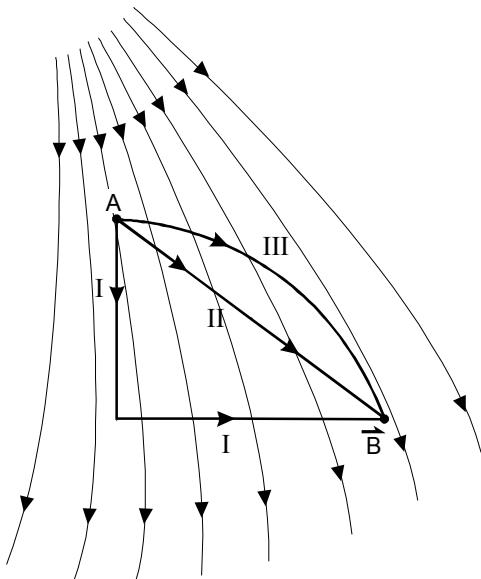
5. If the temperature of the earth were to increase enough to melt the polar ice caps, a portion of the earth's mass would be redistributed away from its axis of rotation. Which of the following statements correctly describes a result of this mass redistribution?

- A. The angular momentum of the earth would increase, causing the earth to rotate faster.
- B. The moment of inertia of the earth would decrease, causing the earth to rotate faster.
- C. The angular momentum of the earth would decrease, causing the earth to rotate more slowly.
- D. The moment of inertia of the earth would increase, causing the earth to rotate more slowly.

6. Which of the following occurs as the temperature of a current-carrying wire increases?

- A. The resistance decreases because thermal energy frees more electrons.
- B. The resistance increases because the wire expands and gets longer.
- C. The resistance decreases because the electrons move faster.
- D. The resistance increases because the free electrons collide more frequently with the metal atoms.

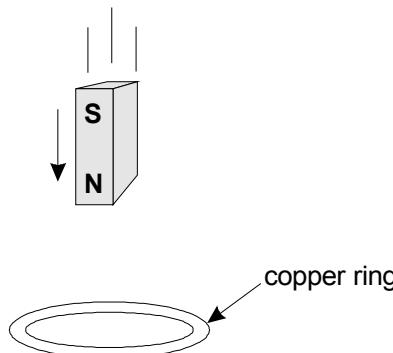
7. Use the diagram below to answer the question that follows.



The diagram shows the lines of force for an electric field, and three different paths linking points A and B. The work required to move a positive charge from point A to point B is evaluated over the three different paths. Which of the following statements about the work required to move the charge from A to B is true?

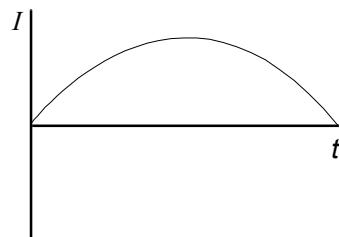
- A. The value of the work will be the same for all of the paths.
- B. The value of the work will be equal to zero for path I.
- C. The value of the work will be greater for path II than for path III.
- D. The value of the work will be greater for path III than for path II.

8. Use the diagram below to answer the question that follows.

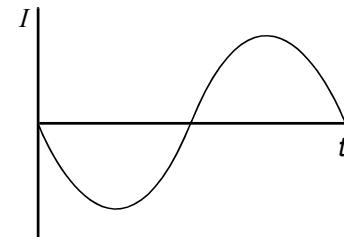


A magnet is passed through a copper ring at a constant speed as shown above. If positive current is defined to be the flow of positive charge in the clockwise direction, as viewed from above the ring, which of the following graphs could represent the current (I) in the ring as a function of time (t)?

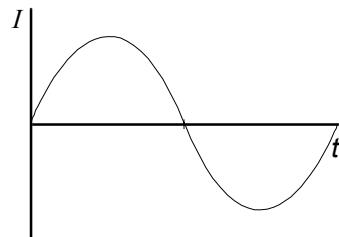
A.



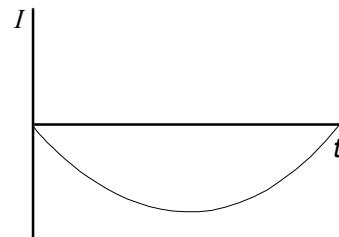
B.



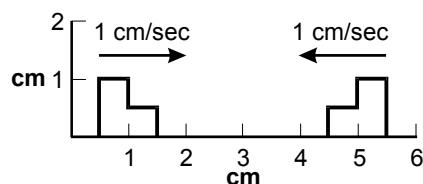
C.



D.

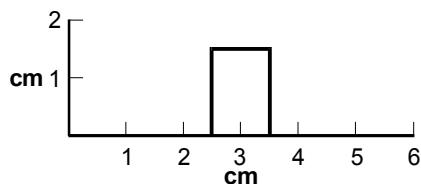


9. Use the diagram below to answer the question that follows.

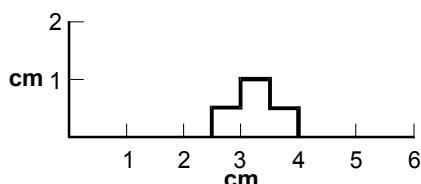


The diagram shows two wave pulses on a string. The wave pulses are traveling toward each other at 1 cm/sec. What does the wave pulse look like 2 seconds later?

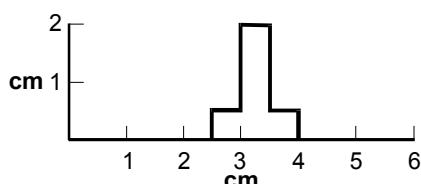
A.



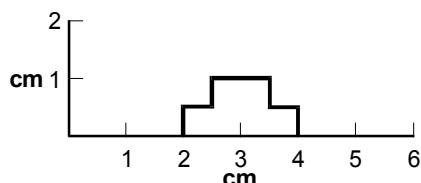
B.



C.



D.



10. Which statement best explains how a microwave oven heats food?

- A. Electromagnetic radiation excites electron transitions in hydrogen atoms. This energy is transmitted to the rest of the food by reradiation.
- B. Electromagnetic radiation excites the nuclei of hydrogen atoms by nuclear magnetic resonance. This energy is transmitted to the rest of the food by conduction.
- C. Electromagnetic radiation excites rotational levels of water molecules. This energy is transmitted to the rest of the food by conduction.
- D. Electromagnetic radiation increases the translational energy of water molecules. This energy is transmitted to the rest of the food by convection.

11. An object is placed 8 cm in front of a thin converging lens that has a focal length of 6 cm. At what distance from the lens will the image of the object be located?

- A. 2 cm
- B. 3.4 cm
- C. 7 cm
- D. 24 cm

12. A nuclear power plant uses uranium fuel to produce electrical power. Energy is lost as heat, since the plant is 33% efficient. If the plant produces 500 MW of useful electrical power, approximately how much mass in the uranium fuel has been lost after one year of continuous operation?

- A. 0.25 kg
- B. 0.52 kg
- C. 0.75 kg
- D. 1.0 kg

Below are the directions for the Physics performance assignment.

DIRECTIONS FOR THE PERFORMANCE ASSIGNMENT

This section of the test consists of a performance assignment. **The assignment can be found on the next page.** You are asked to prepare a written response of approximately 2–3 pages on the assigned topic. You should use your time to plan, write, review, and edit your response for the assignment.

Read the assignment carefully before you begin to work. Think about how you will organize your response. You may use any blank space in this test booklet to make notes, write an outline, or otherwise prepare your response. **However, your score will be based solely on the version of your response written in Written Response Booklet B.**

As a whole, your response must demonstrate an understanding of the knowledge and skills of the field. In your response to the assignment, you are expected to demonstrate the depth of your understanding of the content area through your ability to apply your knowledge and skills rather than merely to recite factual information.

Your response will be evaluated based on the following criteria.

- **PURPOSE:** the extent to which the response achieves the purpose of the assignment
- **SUBJECT MATTER KNOWLEDGE:** appropriateness and accuracy in the application of subject matter knowledge
- **SUPPORT:** quality and relevance of supporting evidence
- **RATIONALE:** soundness of argument and degree of understanding of the subject area

The performance assignment is intended to assess subject knowledge content and skills, not writing ability. However, your response must be communicated clearly enough to permit scorers to make a valid evaluation of your response according to the criteria listed above. Your response should be written for an audience of educators in this field. The final version of your response should conform to the conventions of edited American English. This should be your original work, written in your own words, and not copied or paraphrased from some other work.

Be sure to write about the assigned topic. Please write legibly. You may not use any reference materials during the test. Remember to review your work and make any changes you think will improve your response.

Below is the scoring scale for the Physics performance assignment.

SUBJECT TESTS—PERFORMANCE ASSIGNMENT SCORING SCALE

Score Point	Score Point Description
4	The "4" response reflects a thorough knowledge and understanding of the subject matter. <ul style="list-style-type: none">• The purpose of the assignment is fully achieved.• There is a substantial, accurate, and appropriate application of subject matter knowledge.• The supporting evidence is sound; there are high-quality, relevant examples.• The response reflects an ably reasoned, comprehensive understanding of the topic.
3	The "3" response reflects an adequate knowledge and understanding of the subject matter. <ul style="list-style-type: none">• The purpose of the assignment is largely achieved.• There is a generally accurate and appropriate application of subject matter knowledge.• The supporting evidence is adequate; there are some acceptable, relevant examples.• The response reflects an adequately reasoned understanding of the topic.
2	The "2" response reflects a limited knowledge and understanding of the subject matter. <ul style="list-style-type: none">• The purpose of the assignment is partially achieved.• There is a limited, possibly inaccurate or inappropriate, application of subject matter knowledge.• The supporting evidence is limited; there are few relevant examples.• The response reflects a limited, poorly reasoned understanding of the topic.
1	The "1" response reflects a weak knowledge and understanding of the subject matter. <ul style="list-style-type: none">• The purpose of the assignment is not achieved.• There is little or no appropriate or accurate application of subject matter knowledge.• The supporting evidence, if present, is weak; there are few or no relevant examples.• The response reflects little or no reasoning about or understanding of the topic.
U	The response is unrelated to the assigned topic, illegible, primarily in a language other than English, not of sufficient length to score, or merely a repetition of the assignment.
B	There is no response to the assignment.

Practice Performance Assignment

13. Read the information below; then complete the exercise that follows.

A physics teacher is preparing a lab on the relationship between electrical energy and thermal energy. Each group of students has available a variable DC power source, a multimeter, several resistors of different resistance, a Styrofoam cup with a Styrofoam cover, and a thermometer. Write an essay describing an experiment that uses this equipment and is appropriate for investigating the relationship between electrical and thermal energy. In your essay:

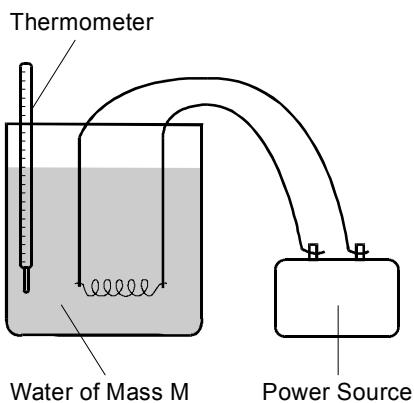
- describe any additional materials and equipment required for this activity;
- describe an appropriate experimental design, including the variables that will be kept constant and the variables that will be manipulated;
- describe what kind of data will need to be gathered and how the data will be collected, recorded, and analyzed; and
- identify two physics concepts that are related to this investigation and explain how the results of this experiment could be used to illustrate these concepts.

Sample Performance Assignment Response: Score Point 4

A lab on the relationship between electrical energy and thermal energy will make use of the principle of conservation of energy. When electric current passes through a circuit, heat is always generated. Heat is a form of energy. According to the law of conservation of energy, the amount of heat generated must be equal to the amount of electrical energy lost in the circuit. The lab will have students verify this by:

1. determining the amount of heat generated by a resistor immersed in a known mass of water contained in a calorimeter by measuring the temperature change of the water;
2. determining the electrical energy dissipated in the resistor by measuring the current through and the voltage drop across the resistor over a given amount of time; and
3. comparing these two values to see if they are the same.

The diagram below shows the experimental setup.



In addition to the materials listed, a balance for massing the amount of water in the calorimeter and a stopwatch for measuring the amount of time current flows through the resistor will also be needed.

In this experiment, the voltage will be kept constant, and the resistance will be varied. **CAUTION:** For safety reasons, the voltage should be kept small (e.g., around 5 volts). Pour a known mass of water in the calorimeter, and take the initial temperature of the water. Set up the equipment as shown, and set the variable voltage to a constant value. Start the timer at the same time that the circuit is closed, and use the multimeter to measure the voltage across and the current through the resistor. Monitor the temperature of the water. After the temperature of the water has changed one or two degrees, open the circuit and stop the timer concurrently. Continue to monitor the temperature until it stops changing. Record the final temperature of the water. Repeat the experiment with different resistors.

(continued on next page)

Sample Performance Assignment Response: Score Point 4 (continued)

Record the data in a table like the one below.

Voltage (volts)	Current (Amps)	Resistance (Ohms)	Total Time (sec)	Elec. Energy (joules)	Mass of Water (g)	Initial Temp. (°C)	Final Temp. (°C)	Change in Heat Energy (joules)

To find the electrical energy, use the fact that the power through a circuit is given by $P = IV$. Since Ohm's law states that $V = IR$, combine these two relationships to get $P = I^2R$. Since power is the rate of change of energy with respect to time, the electrical energy is determined by multiplying by the total time, t . Therefore, the electrical energy is

$$E_E = I^2Rt$$

To find the increase in heat or internal energy of the water, multiply the specific heat of water, c , by the mass, m , and the temperature change, ΔT .

$$E_H = mc\Delta T$$

After the data has been collected, we can determine the percent error in the conversion of electrical energy to heat energy using the following expression:

$$\frac{\text{Electrical Energy} - \text{Heat Energy}}{\text{Electrical Energy}} \times 100$$

If the absolute value of this number is greater than 10%, we should look at our experimental procedure and consider if, for example, the calorimeter was well insulated; the specific heat of the thermometer and the calorimeter should be accounted for; or the current, voltage, and resistance remained constant during the experiment.

This lab will help students understand the concept that energy can be transformed from one type (electrical) to another (heat) and that the total amount of energy in any transformation always remains constant (conservation of energy).

ANSWER KEY

Field 09: Physics

Question Number	Correct Response	Objective
1.	C	Understand principles and procedures of classroom physics investigations.
2.	A	Understand the processes of gathering, organizing, reporting, and analyzing scientific data in the context of physics investigations.
3.	B	Understand the laws of motion (including relativity) and conservation of momentum.
4.	C	Understand the principle of conservation of energy and the concepts of energy, work, and power.
5.	D	Understand the dynamics of rotational motion, including torque, angular momentum, motion with constant angular acceleration, rotational kinetic energy, center of mass, and moment of inertia.
6.	D	Understand characteristics of electric current and components of electric circuits.
7.	A	Understand characteristics and units of electric charge, electric fields, electric potential, and capacitance; and apply principles of static electricity to solve problems involving Coulomb's law and electric fields.
8.	B	Understand and apply the principles of electromagnetic induction and AC circuits.
9.	A	Understand waves, wave motion, and wave interference.
10.	C	Understand the production and characteristics of electromagnetic waves.
11.	D	Understand the principles of reflection and refraction.
12.	B	Understand types and characteristics of nuclear reactions, methods of initiating and controlling them, and applications of nuclear reactions to the generation of electricity.