NEW YORK STATE TEACHER CERTIFICATION EXAMINATIONS™

PREPARATION GUIDE

Physics CST (09)

The University of the State of New York • NEW YORK STATE EDUCATION DEPARTMENT • Office of Teaching Initiatives, Albany, New York 12234

This test is now delivered as a computer-based test. See www.nystce.nesinc.com for current program information.
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INTRODUCTION

Purpose of This Preparation Guide

This preparation guide is designed to help familiarize candidates with the content and format of a test for the New York State Teacher Certification Examinations (NYSTCE®) program. Education faculty and administrators at teacher preparation institutions may also find the information in this guide useful as they discuss the test with candidates.

The knowledge and skills assessed by the test are acquired throughout the academic career of a candidate. A primary means of preparing for the test is the collegiate preparation of the candidate.

This preparation guide illustrates some of the types of questions that appear on a test; however, the set of sample questions provided in this preparation guide does not necessarily define the content or difficulty of an entire actual test. All test components (e.g., directions, question content and formats) may differ from those presented here. The NYSTCE program is subject to change at the sole discretion of the New York State Education Department.

Organization of This Preparation Guide

Contained in the beginning sections of this preparation guide are general information about the NYSTCE program and how the tests were developed, a description of the organization of test content, and strategies for taking the test.

Following these general information sections, specific information about the test described in this guide is presented. The test objectives appear on the pages following the test-specific overview. The objectives define the content of the test.

Next, information about the multiple-choice section of the test is presented, including sample test directions. Sample multiple-choice questions are also presented, with the correct responses indicated and explanations of why the responses are correct.

Following the sample multiple-choice questions, a description of the written assignment section of the test is provided, including sample directions. A sample written assignment is presented next, followed by a sample strong response to the assignment and an evaluation of that response.

For Further Information

If you have questions after reading this preparation guide, you may wish to consult the NYSTCE Registration Bulletin. You can view or print the registration bulletin online at www.nystce.nesinc.com.
GENERAL INFORMATION ABOUT THE NYSTCE

How Were the NYSTCE Tests Developed?

The New York State Teacher Certification Examinations are criterion referenced and objective based. A criterion-referenced test is designed to measure a candidate’s knowledge and skills in relation to an established standard rather than in relation to the performance of other candidates. The explicit purpose of these tests is to help identify for certification those candidates who have demonstrated the appropriate level of knowledge and skills that are important for performing the responsibilities of a teacher in New York State public schools.

Each test is designed to measure areas of knowledge called subareas. Within each subarea, statements of important knowledge and skills, called objectives, define the content of the test. The test objectives were developed for the New York State Teacher Certification Examinations in conjunction with committees of New York State educators.

Test questions matched to the objectives were developed using, in part, textbooks; New York State learning standards and curriculum guides; teacher education curricula; and certification standards. The test questions were developed in consultation with committees of New York State teachers, teacher educators, and other content and assessment specialists.

An individual’s performance on a test is evaluated against an established standard. The passing score for each test is established by the New York State Commissioner of Education based on the professional judgments and recommendations of New York State teachers. Examinees who do not pass a test may retake it at any of the subsequently scheduled test administrations.
Organization of Content

The content covered by each test is organized into **subareas**. These subareas define the major content domains of the test.

Subareas typically consist of several **objectives**. Objectives provide specific information about the knowledge and skills that are assessed by the test.

Each objective is elaborated on by **focus statements**. The focus statements provide examples of the range, type, and level of content that may appear on the tests.

**Test questions** are designed to measure specific test objectives. The number of objectives within a given subarea generally determines the number of questions that will address the content of that subarea on the test. In other words, the subareas that consist of more objectives will receive more emphasis on the test and contribute more to a candidate's test score than the subareas that consist of fewer objectives.

The following example, taken from the field of Social Studies, illustrates the relationship of test questions to subareas, objectives, and focus statements.

```
SOCIAL STUDIES (05)

SUBAREA I—HISTORY

0003 Understand the major political, social, economic, scientific, and cultural developments and turning points that shaped the course of world history from 1500 through 1850.

analyzing the roles, contributions, and diverse perspectives of individuals and groups involved in independence struggles in Latin America

Which of the following was an important goal of nineteenth-century Latin American liberals?

A. establishing governments based on the separation of church and state
B. reducing the influence of competitive individualism in social and economic life
C. creating strong centralized governments
D. making plantation agriculture the foundation of economic development

Each multiple-choice question is designed to measure one of the test objectives.

The focus statements provide examples of the range, type, and level of content that may appear on the test for questions measuring the objective.

The objectives define the knowledge and skills that New York State teachers and teacher educators have determined to be important for teachers to possess.

The field is divided into major content subareas. The number of objectives in each subarea may vary, depending on the breadth of content contained within it.

This is the name and field number of the test.
```
TEST-TAKING STRATEGIES

Be On Time.

Arrive at the test center on time so that you are rested and ready to begin the test when instructed to do so.

Follow Directions.

At the beginning of the test session and throughout the test, follow all directions carefully. This includes the oral directions that will be read by the test administrators and any written directions in the test booklet. The test booklet will contain general directions for the test as a whole and specific directions for individual test questions or groups of test questions. If you do not understand something about the directions, do not hesitate to raise your hand and ask your test administrator.

Pace Yourself.

The test schedule is designed to allow sufficient time for completion of the test. Each test session is four hours in length. The tests are designed to allow you to allocate your time within the session as you need. You can spend as much time on any section of the test as you need, and you can complete the sections of the test in any order you desire; however, you will be required to return your materials at the end of the four-hour session.

Since the allocation of your time during the test session is largely yours to determine, planning your own pace for taking the test is very important. Do not spend a lot of time with a test question that you cannot answer promptly; skip that question and move on. If you skip a question, be sure to skip the corresponding row of answer choices on your answer document. Mark the question in your test booklet so that you can return to it later, but be careful to appropriately record on the answer document the answers to the remaining questions.

You may find that you need less time than the four hours allotted in a test session, but you should be prepared to stay for the entire time period. Do not make any other commitments for this time period that may cause you to rush through the test.

Read Carefully.

Read the directions and the questions carefully. Read all response options. Remember that multiple-choice test questions call for the “best answer”; do not choose the first answer that seems reasonable. Read and evaluate all choices to find the best answer. Read the questions closely so that you understand what they ask. For example, it would be a waste of time to perform a long computation when the question calls for an approximation.

Read the test questions, but don’t read into them. The questions are designed to be straightforward, not tricky.
Mark Answers Carefully.

Your answers for all multiple-choice questions will be scored electronically; therefore, the answer you select must be clearly marked and the only answer marked. If you change your mind about an answer, erase the old answer completely. Do not make any stray marks on the answer document; these may be misinterpreted by the scoring machine.

IF YOU SKIP A MULTIPLE-CHOICE QUESTION, BE SURE TO SKIP THE CORRESPONDING ROW OF ANSWER CHOICES ON YOUR ANSWER DOCUMENT.

You may use any available space in the test booklet for notes, but your answers and your written response must be clearly marked on your answer document. ONLY ANSWERS AND WRITTEN RESPONSES THAT APPEAR ON YOUR ANSWER DOCUMENT WILL BE SCORED. Answers and written responses in your test booklet will not be scored.

Guessing

As you read through the response options, try to find the best answer. If you cannot quickly find the best answer, try to eliminate as many of the other options as possible. Then guess among the remaining answer choices. Your score on the test is based on the number of test questions that you have answered correctly. There is no penalty for incorrect answers; therefore, it is better to guess than not to respond at all.

Passages or Other Presented Materials

Some test questions are based on passages or other presented materials (e.g., graphs, charts). You may wish to employ some of the following strategies while you are completing these test questions.

One strategy is to read the passage or other presented material thoroughly and carefully and then answer each question, referring to the passage or presented material only as needed. Another strategy is to read the questions first, gaining an idea of what is sought in them, and then read the passage or presented material with the questions in mind. Yet another strategy is to review the passage or presented material to gain an overview of its content, and then answer each question by referring back to the passage or presented material for the specific answer. Any of these strategies may be appropriate for you. You should not answer the questions on the basis of your own opinions but rather on the basis of the information in the passage or presented material.

Check Accuracy.

Use any remaining time at the end of the test session to check the accuracy of your work. Go back to the test questions that gave you difficulty and verify your work on them. Check the answer document, too. Be sure that you have marked your answers accurately and have completely erased changed answers.
ABOUT THE PHYSICS TEST

The purpose of the Physics Content Specialty Test (CST) is to assess knowledge and skills in the following six subareas:

- **Subarea I.** Foundations of Scientific Inquiry
- **Subarea II.** Mechanics and Thermodynamics
- **Subarea III.** Electricity and Magnetism
- **Subarea IV.** Waves, Sound, and Light
- **Subarea V.** Quantum Theory and the Atom
- **Subarea VI.** Foundations of Scientific Inquiry: Constructed-Response Assignment

The test objectives presented on the following pages define the content that may be assessed by the Physics CST. Each test objective is followed by focus statements that provide examples of the range, type, and level of content that may appear on the test for questions measuring that objective.

The test contains approximately 90 multiple-choice test questions and one constructed-response (written) assignment. The figure below illustrates the approximate percentage of the test corresponding to each subarea.

The section that follows the test objectives presents sample test questions for you to review as part of your preparation for the test. To demonstrate how each objective may be assessed, a sample question is presented for each objective. For objectives 7 and 14, a passage and two questions are presented. The correct response and an explanation of why the response is correct follow each question. A sample written assignment is also presented, along with an example of a strong response to the assignment and an evaluation of that response.

The sample questions are designed to illustrate the nature of the test questions; they should not be used as a diagnostic tool to determine your individual strengths and weaknesses.

A section containing a constants chart and formulas pages will be provided in the Physics test booklet. A sample constants chart and formulas pages can be found before the sample Physics test questions in this guide.
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.
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
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

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

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
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
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
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)

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

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
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
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.
MULTIPLE-CHOICE SECTION

This preparation guide provides sample multiple-choice questions and a sample written assignment for the test. The multiple-choice questions illustrate the objectives of the test—one sample question for each objective. For objectives 7 and 14, a passage and two questions are presented.

Three pieces of information are presented for each test question:

1. the number of the test objective that the sample question illustrates,
2. a sample test question,
3. an indication of the correct response and an explanation of why it is the best available response.

Keep in mind when reviewing the questions and response options that there is one best answer to each question. Remember, too, that each explanation offers one of perhaps many perspectives on why a given response is correct or incorrect in the context of the question; there may be other explanations as well.

On the following page are sample test directions similar to those that candidates see when they take the test.
SAMPLE TEST DIRECTIONS FOR MULTIPLE-CHOICE QUESTIONS

DIRECTIONS

This test booklet contains a multiple-choice section and a section with a single written assignment. You may complete the sections of the test in the order you choose.

Each question in the first section of this booklet is a multiple-choice question with four answer choices. Read each question CAREFULLY and choose the ONE best answer. Record your answer on the answer document in the space that corresponds to the question number. Completely fill in the space that has the same letter as the answer you have chosen. *Use only a No. 2 lead pencil.*

**Sample Question:** 1. What is the capital of New York?
   A. Buffalo
   B. New York City
   C. Albany
   D. Rochester

The correct answer to this question is C. You would indicate that on the answer document as follows:

1. [ ] A [ ] B [ ] C [ ] D

You should answer all questions. Even if you are unsure of an answer, it is better to guess than not to answer a question at all. You may use the margins of the test booklet for scratch paper, but you will be scored only on the responses on your answer document.

The directions for the written assignment appear later in this test booklet.

FOR TEST SECURITY REASONS, YOU MAY NOT TAKE NOTES OR REMOVE ANY OF THE TEST MATERIALS FROM THE ROOM.

The words "End of Test" indicate that you have completed the test. You may go back and review your answers, but be sure that you have answered all questions before raising your hand for dismissal. Your test materials must be returned to a test administrator when you finish the test.

If you have any questions, please ask them now before beginning the test.

STOP

DO NOT GO ON UNTIL YOU ARE TOLD TO DO SO.
## CONSTANTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration of gravity on Earth ((g))</td>
<td>9.8 m/s(^2)</td>
</tr>
<tr>
<td>Speed of light in a vacuum ((c))</td>
<td>(3.00 \times 10^8) m/s</td>
</tr>
<tr>
<td>Planck's constant ((h))</td>
<td>(6.63 \times 10^{-34}) J(\cdot)s = (4.14 \times 10^{-15}) eV(\cdot)s</td>
</tr>
<tr>
<td>Electron rest mass</td>
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</tr>
<tr>
<td>Proton rest mass</td>
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</tr>
<tr>
<td>Charge of electron</td>
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</tr>
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<td>Coulomb's constant ((k_e))</td>
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<tr>
<td>Boltzmann's constant ((k))</td>
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</tr>
<tr>
<td>Gas constant ((R))</td>
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<tr>
<td>Gravitational constant ((G))</td>
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</tr>
<tr>
<td>Permeability of free space ((\mu_0))</td>
<td>(4\pi \times 10^{-7}) T(\cdot)m/A</td>
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<tr>
<td>Avogadro's number</td>
<td>(6.02 \times 10^{23}) particles/mole</td>
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## FORMULAS

<table>
<thead>
<tr>
<th>Description</th>
<th>Formula</th>
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| Constant acceleration | \(v = v_i + at\)  
                      | \(x = x_i + v_i t + \frac{1}{2}at^2\)  
                      | \(v_f^2 - v_i^2 = 2a(x_f - x_i)\) |
| Circular motion  | \(a = \frac{v^2}{r}\)  
                      | \(\theta = \theta_i + \omega t + \frac{1}{2}at^2\)  
                      | \(\omega = \omega_i + at\)  
                      | \(v = r\omega\)  
                      | \(a = r\alpha\)  
<pre><code>                  | \(\tau = I\alpha\) |
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<tr>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
</table>
| 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          | \( v = \sqrt{\frac{RT}{M}} \) |
| Speed of waves in a string              | \( v = \sqrt{\frac{T}{\mu}} \) |
| Standing wave condition for a string fixed at both ends | \( 2L = n\lambda, n \) is an integer |
| Standing wave condition for a string fixed at one end | \( 4L = n\lambda, n \) is odd |
| Optics                                  | \( n_1 \sin \theta_1 = n_2 \sin \theta_2 \)  
\( n = \frac{c}{v} \)  
\( \frac{1}{f} = \frac{1}{p} + \frac{1}{q} \) |
| Thermodynamics                          | \( \Delta U = nC_v \Delta T \)  
\( \Delta Q = mc \Delta T \)  
\( PV = nRT \)  
\( \frac{1}{2}m\vec{v}^2 = \frac{3}{2}kT \) |
| Fluids                                  | \( p = \rho gh \) |
| Magnetism                               | \( \vec{F} = q\vec{v} \times \vec{B} \)  
\( \vec{F} = I\vec{l} \times \vec{B} \)  
\( \oint \vec{B} \cdot d\vec{l} = \mu_0 I \)  
\( \mathcal{E}_{\text{ave}} = -\frac{\Delta \phi}{\Delta t} \)  
\( \phi = B_\perp A \) |
## FORMULAS (continued)

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<td>$\mathcal{E} = -L \frac{dI}{dt}$</td>
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<td></td>
<td>$\omega_0 = \frac{1}{\sqrt{LC}}$</td>
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<td></td>
<td>$X_L = \omega L$</td>
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<td>$X_C = \frac{1}{\omega C}$</td>
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<td>$Z = \sqrt{(X_C - X_L)^2 + R^2}$</td>
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<td>Photoelectric effect</td>
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<td>Wave-particle relations</td>
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<td></td>
<td>$h = p\lambda$.</td>
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### 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.
Objective 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.

1. Which of the following individuals quantified the law of the lever and the law associated with fluid displacement and buoyancy?
   A. Archimedes  
   B. Leonardo da Vinci  
   C. Galileo  
   D. Pascal

Correct Response: A. Archimedes, one of the greatest mathematicians and physicists of the ancient world, applied the law of the lever to determine the center of gravity of various plane figures and conic sections. His law of buoyancy, known as Archimedes' principle, states that the buoyant force on an object submerged in a fluid is equal to the weight of the displaced fluid. Archimedes applied this principle to find the position of equilibrium of objects floating in a liquid.
Objective 0002
Understand the process of scientific inquiry and the role of observation and experimentation in explaining natural phenomena.

2. When evaluating the results of a scientific investigation, which of the following questions about the research is most critical to answer?
   
   A. Has the investigation taken other recent work into account?
   
   B. Do the data support the conclusions stated in the study?
   
   C. Are the conclusions supported by other research on the topic?
   
   D. Is the researcher well respected among leaders in the field?

Correct Response: B. The criterion for evaluating a scientific statement is to determine how well the statement is supported by empirical observations and data. Thus, in evaluating the results of a scientific investigation, it is most critical that the conclusion of the study be supported by the data collected during the investigation.
Objective 0003
Understand the processes of gathering, organizing, reporting, and interpreting scientific data and apply this understanding in the context of physics investigations.

3. Which of the following best describes how degrees of complexity of a system are influenced by the scale at which the system is investigated?

A. The principle that energy is conserved in simple machines does not hold when an atom emits a photon due to electron transitions.

B. The law determining the gravitational pull between the sun and planets does not describe the gravitational force between small meteors.

C. The Newtonian concepts of force and acceleration apply to neutral matter but fail to correctly predict the acceleration of a charged object in an electric field.

D. The laws of physics for large objects are deterministic while the behavior of subatomic particles is based on probability.

Correct Response: D. The familiar large-scale world we see around us is governed by the principles of Newtonian mechanics, whose laws allow us to predict the future state of a system, given enough information about its current state. In the subatomic realm, Newtonian mechanics is superseded by quantum mechanics, a theory in which the likelihood of events is based on probability. It follows that the complexity and predictability of a system are different depending upon the scale at which the system is investigated.
Objective 0004
Understand principles and procedures of measurement and the safe and proper use of equipment and materials used in physics investigations.

4. Which of the following best expresses the scientific definition of experimental precision?

A. the agreement among several measurements that have been made in the same way
B. the number of decimal points used to record a measurement
C. the closeness of a measurement to the accepted value for a specific physical quantity
D. the ratio of the median value of a set of measurements to the number of measurements

Correct Response: A. When a number of scientific experiments measure the same phenomenon, the extent to which the results of the experiments replicate each other is defined as experimental precision. This is a separate issue from the number of significant digits to which the measurement is made, the closeness of the measurements to the accepted value, and statistical measurements of the data, such as median.
Objective 0005

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

5. Use the graph below to answer the question that follows.

The current in a circuit is measured as a function of time and the data are plotted as $\ln[I(t)]$ on the vertical axis and $t$ on the horizontal axis. If the current is given by an equation of the form $I(t) = Ce^{bt}$, what are the approximate values for $C$ and $b$, respectively?

A. $C = 0.25$, $b = -2.3$
B. $C = 0.25$, $b = -10.27$
C. $C = -10.27$, $b = -0.25$
D. $C = 10.27$, $b = -0.25$

Correct Response: D. Taking the natural logarithm of both sides of the equation for the current and using the laws of logarithms results in $\ln[I(t)] = \ln[Ce^{bt}] = \ln[C] + \ln[e^{bt}] = \ln[C] + bt$. Therefore $\ln[I(t)] = bt + \ln[C]$ is a linear equation in $t$, where $b$ is the slope of the line and $\ln[C]$ is the $y$-intercept. From the graph, the slope of the line is $\frac{0.33 - (-2.33)}{8 - 0} = -0.25$. From the graph, the $y$-intercept is approximately $2.33 = \ln[C]$. This equation can be solved by taking the inverse natural logarithm of both sides, which results in $C = 10.27$. 
Objective 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.

6. A person is riding a bicycle at a constant velocity of 7.0 m/s on level ground. The cyclist reaches a downhill section and coasts for 105 m at a constant acceleration of 1.5 m/s\(^2\). What is the velocity of the cyclist at the bottom of the hill?

A. 13 m/s
B. 16 m/s
C. 19 m/s
D. 25 m/s

Correct Response: C. The cyclist's initial velocity on the downhill section is given as 7.0 m/s, and the cyclist accelerates at a constant acceleration of 1.5 m/s\(^2\) for 105 m. Given the initial velocity, the acceleration, and the displacement, the equation \(v_f^2 = v_i^2 + 2a\Delta x\) can be used to find the final velocity. Substituting the given values \(v_i = 7.0\) m/s, \(a = 1.5\) m/s\(^2\) and \(\Delta x = 105\) m gives answer choice C, 19 m/s.
Use the diagram below to answer the two questions that follow.

A mass $m$ rests on a horizontal surface. A rope is attached to the mass and pulled in the direction shown with a force of $\vec{F}_a$. The magnitude of the frictional force will be denoted by $F_f$. 
Objective 0007
Understand characteristics of forces and methods used to measure force, and solve problems involving forces.

7. Which of the following equations correctly describes the net forces acting on the mass in the $x$-direction?

A. $\sum F_x = F_a \sin 30^\circ - F_f$
B. $\sum F_x = F_a \sin 30^\circ + F_f \sin 30^\circ$
C. $\sum F_x = F_a \cos 30^\circ - F_f$
D. $\sum F_x = F_a \cos 30^\circ + F_f \cos 30^\circ$

Correct Response: C. The net force in the $x$-direction is the sum of all the forces acting in that direction, including the $x$-component of any oblique forces (that is, forces acting at an angle to the $x$- and $y$-axes). The $x$-component of the rope's force, $F_a$, is found from right-angle trigonometry to be $F_a \cos 30^\circ$, because the $x$-component is adjacent to the $30^\circ$ angle. The force of friction also lies on the $x$-axis, but in the opposite direction, so it appears as $-F_f$. The sum of those two forces in the $x$-direction is $\sum F_x = F_a \cos 30^\circ - F_f$. 
Objective 0007
Understand characteristics of forces and methods used to measure force, and solve problems involving forces.

8. Which of the following equations correctly describes the net forces acting on the mass in the y-direction?

A. $\sum F_y = F_a \sin 30^\circ + mg - N$
B. $\sum F_y = F_a \sin 30^\circ - mg + N$
C. $\sum F_y = F_a \cos 30^\circ + mg - N$
D. $\sum F_y = F_a \cos 30^\circ - mg + N \cos 30^\circ$

Correct Response: B. The net force in the y-direction is the sum of all the forces acting in that direction, including the y-component of any oblique forces (that is, forces acting at an angle to the x- and y-axes). The y-component of the rope's force, $F_a$, is found from right-angle trigonometry to be $F_a \sin 30^\circ$, because the y-component is opposite the $30^\circ$ angle. There is also a normal force $N$ acting on the mass in the positive y-direction, and the weight of the mass $mg$ acts downward, and therefore is written as $-mg$ in the equation. The sum of those three forces in the y-direction is $\sum F_y = F_a \sin 30^\circ - mg + N$. 


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

9. A box with a mass of 2.0 kg accelerates down a rough 45° slope at 5.7 m/s^2. What is the magnitude of the frictional force acting on the box?

A. 1.2 N  
B. 2.5 N  
C. 8.2 N  
D. 25 N

Correct Response: B. When the forces acting on the mass are resolved into components, it is found that the component of the weight of the box acting down the incline is \( mg \sin 45° \). The frictional force \( F_f \) acts up the incline (in the direction opposite to the mass’s motion). The normal force on the mass acts perpendicularly to the incline, so it does not have a component in the direction of motion. The net force on the mass in the direction of motion is therefore \( F_{\text{net}} = ma = mg \sin 45° - F_f \). Substituting 2.0 kg for \( m \), 5.7 m/s^2 for \( a \), and 9.8 m/s^2 for \( g \), and then solving for \( F_f \) yields the correct response, 2.5 N.
Objective 0009
Understand and apply the principle of conservation of energy and the concepts of energy, work, and power.

10. **Use the diagram below to answer the question that follows.**

![Diagram of a playground swing]

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 $\theta$ is 45°?

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

Correct Response: C. Define the potential energy at the lowest point of the path of the swing to be zero. At this point the swing attains its maximum speed and its total mechanical energy is kinetic energy only. When the swing is at its maximum height, $h_{\text{max}} (\theta = 45^\circ)$, the total energy is potential energy only. By the principle of the conservation of mechanical energy, $mgh_{\text{max}} = \frac{1}{2}mv_{\text{max}}^2$, or $v_{\text{max}} = \sqrt{2gh_{\text{max}}}$. Using triangle trigonometry, $h_{\text{max}} = 2 \text{ m} - 2 \cos 45^\circ \text{ m} = .586 \text{ m}$. Using $g = 9.8 \text{ m/s}^2$ and substituting these values into the above expression results in $v_{\text{max}} = 3.39 \text{ m/s}$. 


Objective 0010

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

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

The compound wheel shown above has a moment of inertia of 5 kg·m², an exterior radius of 0.50 m, and an interior radius of 0.20 m. A 4.0 N force and a 7.0 N force are applied as shown. What is the angular acceleration of the wheel?

A. 0.12 rad/s²
B. 0.52 rad/s²
C. 0.68 rad/s²
D. 2.2 rad/s²

Correct Response: C. Newton's second law of motion for rotation is $\sum \tau = I\alpha$, where $\sum \tau$ is the sum of the torques on an object, $I$ is the object's moment of inertia, and $\alpha$ is its angular acceleration. The two torques acting on the compound wheel, which act in the same direction, are given by $\sum \tau = r_1F_1 + r_2F_2 = (0.20 \text{ m})(7.0 \text{ N}) + (0.50 \text{ m})(4.0 \text{ N}) = 3.4 \text{ N·m}$. Substituting into the torque equation and solving for $\alpha$ yields 0.68 rad/s².
12. An ice cube is removed from a freezer, placed on an insulated surface, and allowed to melt. Which of the following best describes why the entropy of the water increases as it melts?

A. The entropy increases because the temperature of the ice increases as it melts.

B. The entropy increases because the forces between water molecules are greater in the liquid phase than in the solid phase.

C. The entropy increases because the specific heat of water is greater than the specific heat of ice.

D. The entropy increases because the molecular arrangement of the molecules in the liquid state is less ordered than in the solid state.

Correct Response: D. One definition of entropy is a measure of the disorder of the particles in a system. In the case of a melting solid, the system is going from a more ordered state to a more disordered state, because the molecules in a solid are in a more rigid and orderly arrangement than that of the molecules in a liquid.
Objective 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.

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

Two positive point charges \( q_1 \) and \( q_2 \) are separated by a distance \( a \). What is the magnitude of the electric field at point \( X \), which lies on the line connecting \( q_1 \) and \( q_2 \) at a distance \( b \) from \( q_2 \) where \( k \) is the electrical constant?

A. \( \frac{kq_1q_2}{(a + b)^2} \)

B. \( \frac{kq_1}{a^2} + \frac{kq_2}{b^2} \)

C. \( \frac{2kq_1q_2}{(a + b)^2} \)

D. \( \frac{kq_1}{(a + b)^2} + \frac{kq_2}{b^2} \)

Correct Response: D. The electric field due to a point charge \( q \) is given by \( E = \frac{kq}{r^2} \), where \( r \) is the distance from the charge. Point \( X \) is a distance \( a + b \) from charge \( q_1 \), so that the electric field due to \( q_1 \) at point \( X \) is \( \frac{kq_1}{(a + b)^2} \). Point \( X \) is a distance \( b \) from charge \( q_2 \), so that the electric field due to \( q_2 \) at point \( X \) is \( \frac{kq_2}{b^2} \). The total field at point \( X \) is the sum of these two fields, which, since they are in the same direction, is \( E = \frac{kq_1}{(a + b)^2} + \frac{kq_2}{b^2} \).
Objective 0013
Understand and analyze characteristics of DC circuits.

14. **Use the diagram below to answer the question that follows.**

![Diagram of a circuit consisting of four 1.5 V cells, a switch, and a small light bulb.]

The diagram represents a circuit consisting of four 1.5 V cells, a switch, and a small light bulb. When the circuit is closed, how much work is required to move 0.10 C of charge through the light bulb?

A. 0.15 J  
B. 0.60 J  
C. 15 J  
D. 60. J

Correct Response: B. The four 1.5 V cells connected in series provide 6.0 V of electric potential to the circuit. The work needed to move a charge $Q$ through a potential difference of $\Delta V$ is $Q\Delta V$. In this series circuit, the potential difference across the light bulb is the same as the potential difference provided by the battery, or 6.0 V. Therefore, moving 0.10 C of charge through the light bulb requires $Q\Delta V = (0.10 \text{ C})(6.0 \text{ V}) = 0.60 \text{ J}$ of energy.
Use the diagram below to answer the two questions that follow.

The diagram represents the lines of force for a uniform magnetic field. The field lines are pointing out of the page. The vector represents a proton with velocity vector $v$ in the field.
Objective 0014
Understand magnets, electromagnets, and magnetic fields; the effects of magnetic fields on moving electric charges; and the applications of electromagnetism.

15. Which of the following shows the direction of the magnetic force on the proton?

A. ↑
B. →
C. ↓
D. ←

Correct Response: B. The magnetic force on a charged particle moving in a magnetic field is given by \( \mathbf{F}_B = q \mathbf{v} \times \mathbf{B} \), where \( q \) is the charge, \( \mathbf{v} \) is its velocity, and \( \mathbf{B} \) is the magnetic field. The direction of \( \mathbf{F}_B \) is given by the right-hand rule, in which \( \mathbf{v} \) is crossed into \( \mathbf{B} \). Thus, with the right hand open and the back of the hand lying flat on the paper so the \( \mathbf{B} \) vectors are perpendicular to the palm, the fingers pointing in the direction of \( \mathbf{v} \), and the thumb extended perpendicular to the fingers, the thumb points in the direction of \( \mathbf{F} \), which is to the right.
Objective 0014
Understand magnets, electromagnets, and magnetic fields; the effects of magnetic fields on moving electric charges; and the applications of electromagnetism.

16. What type of curve describes the trajectory of the proton in the magnetic field?
   A. line
   B. parabola
   C. circle
   D. hyperbola

Correct Response: C. According to the right-hand rule, the magnetic force on the proton is always perpendicular to the direction of its velocity. According to Newton's second law of motion, the proton's acceleration is in the same direction as the magnetic force, so that the proton's acceleration is always perpendicular to the direction of its motion. This is a characteristic of centripetal force and the proton therefore travels in a circle.
Objective 0015
Understand and apply the principles of electromagnetic induction and AC circuits.

17. 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, which of the following graphs could represent the current ($I$) in the ring as a function of time ($t$)?

A. \[ \text{Graph A} \]

B. \[ \text{Graph B} \]

C. \[ \text{Graph C} \]

D. \[ \text{Graph D} \]

Correct Response: D. According to Lenz's law, the current induced in the ring will be in a direction to oppose the change in magnetic flux through the ring. As the north pole of the magnet approaches the ring, the magnetic flux through the ring due to the bar magnet increases in the downward direction. A current will be induced in the ring in a direction that produces an upward magnetic flux, which means the induced current must be clockwise. After the magnet has passed halfway through the ring, the magnetic flux through the ring due to the bar magnet will be decreasing in the downward direction. A current will be induced in the ring in a direction that produces a downward magnetic flux, which means the induced current must be counter-clockwise. This event corresponds to first a negative and then a positive current in the ring.
Objective 0016
Understand the properties and behavior of waves.

18. The velocity of sound in aluminum is $5.1 \times 10^3$ m/s. The frequency of the note middle C is 262 Hz. What is the wavelength of a middle C sound wave in aluminum?

A. $7.4 \times 10^{-2}$ m

B. 5.1 m

C. 19 m

D. $1.3 \times 10^3$ m

Correct Response: C. For any wave, including sound, the relationship between the wave's velocity $v$, frequency $f$, and wavelength $\lambda$ is given by $v = f \lambda$. Substituting the given values for the velocity of sound in aluminum and the frequency of the note, and solving for the wavelength, yields 19.5 m. Thus the correct response is 19 m.
Objective 0017
Understand and apply knowledge of the characteristics, production, and transmission of sound waves.

19. A clarinet and a violin each play the same note of the musical scale at the same volume. The two notes have different sound qualities because the sound waves associated with the notes:

A. have different frequencies.
B. have different overtone series.
C. have different amplitudes.
D. have different phase constants.

Correct Response: B. Since the two instruments are playing the same note at the same volume, the two sounds have the same frequency and amplitude. However, the parts of each instrument that vibrate to produce sound are unique to the instrument. Even if the two instruments are vibrating at the same basic frequency, the modes of vibration create overtones that differ from instrument to instrument. It is these overtone vibrations that give an instrument its unique sound qualities.
Objective 0018
Understand the production and characteristics of electromagnetic waves.

20. 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 re-radiation.

   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 increases the translational energy of water molecules. This energy is transmitted to the rest of the food by convection.

   D. Electromagnetic radiation excites rotational levels of water molecules. This energy is transmitted to the rest of the food by conduction.

Correct Response: D. According to classical electrodynamics, electromagnetic radiation consists of oscillating electric and magnetic fields that propagate through a vacuum at the speed of light. These fields exert forces and/or torques on charged particles. Microwaves are part of the electromagnetic spectrum with a frequency close to the resonant frequency of rotation of the water molecules, which causes them to rotate vigorously. This rotational thermal energy is then transmitted to the rest of the food by collisions between molecules, which is conduction.
Objective 0019
Understand and apply the characteristics of reflective and refractive devices.

21. **Use the diagram below to answer the question that follows.**

![Diagram]

The diagram shows a mirror viewed from above. An object is located at $X$ and two observers are located at $A$ and $B$. Who is able to see the image of the object in the mirror?

A. Both the observer at $A$ and the observer at $B$ can see the image.

B. Neither the observer at $A$ nor the observer at $B$ can see the image.

C. The observer at $A$ can see the image but the observer at $B$ cannot see the image.

D. The observer at $A$ cannot see the image but the observer at $B$ can see the image.

Correct Response: D. An object is visible in a mirror if light reflects off the object, then reflects off the mirror, and then travels to the eyes of an observer. When the light reflects off the mirror, it obeys the law of reflection which states that the reflection angle is equal to the incident angle. Thus, if the path of a typical light ray is drawn from the object $X$ to the mirror, it will follow a slanted path up and to the left in the diagram. After reflection off the mirror, it will continue down and to the left, towards observer $B$. Therefore, only observer $B$ will be able to see the object $X$ in the mirror.
Objective 0020
Understand the dual nature of light and matter.

22. Which of the following situations is generally analyzed using the particle theory of light?

A. the diffraction pattern produced as light passes through a circular aperture

B. the energy of electrons emitted by light incident on a photosensitive metal

C. the polarization effects as light passes through an optical filter

D. the spherical aberration produced by small defects in optical lenses

Correct Response: B. Some phenomena of light are treated as aspects of light's particle nature and some as aspects of light's wave nature. In the photoelectric effect, a discrete packet of light—i.e., a particle of light called a photon—strikes a metal surface and, if the light has enough energy, causes an electron to be emitted from the metal surface.
Objective 0021
Understand physical models of atomic structure and the nature of elementary particles.

23. Which of the following statements best describes the difference between the Bohr model and the contemporary model of the atom?

A. The Bohr model assumes a neutral nucleus whereas the contemporary model assumes that electrons orbit around a positive nucleus.

B. The Bohr model assumes a continuous range for the orbital radius whereas the contemporary model assumes discrete, nonradiating radii.

C. The Bohr model assumes that photons are emitted from the nucleus whereas the contemporary model assumes they arise from electron transitions.

D. The Bohr model assumes well-defined orbital paths for electrons whereas the contemporary model assumes a spatial probability distribution.

Correct Response: D. In the Bohr model of the atom, electrons follow definite orbital paths of calculable and discrete radii around a positively charged nucleus. This theory of the early twentieth century has been superceded by the quantum mechanical model of the atom, in which the electrons' locations in the atom can no longer be precisely specified but are instead predicted from a probability function. Therefore, choice D is correct.
Objective 0022
Understand the standard model of particle physics.

24. According to the Standard Model, which of the following must be conserved during all reactions involving fundamental particles?

A. the total number of particles
B. the total mass
C. the total electric charge
D. the total electromagnetic energy density

Correct Response: C. According to the Standard Model of particle physics, certain quantities must be the same, or conserved, before and after a reaction involving fundamental particles. Some of these conserved quantities include angular momentum, mass-energy, spin, and electric charge.
25. Use the diagram below to answer the question that follows.

The diagram shows a Geiger counter, a device commonly used to measure the intensity of radiation. Which of the following statements best describes how this device works?

A. Charged radiation passes through the gas to the anode. A voltage is produced as charge builds up on the anode.

B. Radiation ionizes the gas in the tube. The ions flow toward the cathode or anode and cause a voltage pulse.

C. Radiation traveling through the gas in the tube induces a magnetic field. The magnetic field causes an electric current to flow.

D. Radiation energizes the electrons of the gas in the chamber. The photons produced as the electrons return to ground state bombard the metal tube and cause a current to flow.

Correct Response: B. In a Geiger counter, ionizing radiation enters the counter through a thin window and travels through a gas inside the counter's chamber, ionizing some of the gas molecules. Positive ions then travel to the cathode (negative), and negative ions travel to the anode (positive). When the ions reach the cathode or anode they cause a change in the voltage between the two which is detected by the counter, producing the familiar clicking noise.
WRITTEN ASSIGNMENT SECTION

On the following pages are:

- Sample test directions for the written assignment section
- A sample written assignment
- An example of a strong response to the assignment
- The performance characteristics and scoring scale
- An evaluation of the strong response

On the actual test, candidates will be given a different written assignment from the one provided as a sample in this preparation guide.
DIRECTIONS FOR THE WRITTEN ASSIGNMENT

This section of the test consists of a written assignment. You are to prepare a written response of about 150–300 words on the assigned topic. The assignment can be found on the next page. You should use your time to plan, write, review, and edit your response to the assignment.

Read the assignment carefully before you begin to write. Think about how you will organize your response. You may use any blank space provided on the following pages to make notes, write an outline, or otherwise prepare your response. However, your score will be based solely on the response you write on the lined pages of your answer document.

Your response will be evaluated on the basis of the following criteria.

- **PURPOSE:** Fulfill the charge of the assignment.

- **APPLICATION OF CONTENT:** Accurately and effectively apply the relevant knowledge and skills.

- **SUPPORT:** Support the response with appropriate examples and/or sound reasoning reflecting an understanding of the relevant knowledge and skills.

Your response will be evaluated on the criteria above, not on writing ability. However, your response must be communicated clearly enough to permit valid judgment of your knowledge and skills. 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 what you have written and make any changes that you think will improve your response.
Use the graph below to complete the exercise that follows.

The graph shows the current flowing through an inductor with respect to time. Use this graph to create a response in which you analyze properties of this circuit element. In your response:

- given that current is the rate of change of electric charge with respect to time:
  1. describe how the above graph can be used to determine the charge flowing through the inductor; and
  2. determine the net charge through the inductor from $t = 0.0 \text{ s}$ to $t = 10.0 \text{ s}$.

- given that the voltage across the inductor is directly proportional to the negative of the rate of change of current with respect to time, and that the constant of proportionality is $1.0 \text{ mH}$:
  1. describe how the above graph can be used to determine the voltage across the inductor; and
  2. sketch a free-hand graph that shows the voltage with respect to time from $t = 0.0 \text{ s}$ to $t = 10.0 \text{ s}$.
STRONG RESPONSE TO THE SAMPLE WRITTEN ASSIGNMENT

1. Given that \( I = \frac{dq}{dt} \), this implies that \( q = \int I dt \), which is the area under the 
\( I \) vs \( t \) graph. The net charge can be determined by summing the areas from \( t = 0.0s \) to 
\( t = 1.0s \), \( t = 2.0s \) to \( t = 3.0s \), \( t = 4.0s \) to \( t = 6.0s \), and \( t = 7.0s \) to \( t = 10.0s \), where the 
area from \( t = 7.0s \) to \( t = 10.0s \) has a negative value.

2. \[ q = \frac{1}{2} (1.0 \text{ s})(4.0 \text{ mA}) + \frac{1}{2} (1.0 \text{ s})(4.0 \text{ mA}) + \frac{1}{2} (2.0 \text{ s})(4.0 \text{ mA}) - \frac{1}{2} (3.0 \text{ s})(5.0 \text{ mA}) \] 
\[ q = 0.5 \text{ mA} \cdot \text{s} = 0.5 \text{ mC} \]

1. Given that \( E = k \left( \frac{-dI}{dt} \right) \) where \( k = 1.0\text{mH} \), then \( -\frac{dI}{dt} \) equals the negative of the slope of 
the \( I \) vs \( t \) graph. The voltage across the inductor can be found by multiplying the 
negative of the slope of the \( I \) vs \( t \) graph by \( 1.0\text{mH} \).

2. The slopes of the graph segments are:

\[ \begin{align*}
0-1.0 \text{ s} & \quad \frac{4.0 \text{ mA} - 0}{1.0 \text{ s}} = 4.0 \frac{\text{mA}}{\text{s}} \\
2.0 \text{ s} \text{ to } 3.0 \text{ s} & \quad \frac{4.0 \text{ mA} - 0}{1.0 \text{ s}} = 4.0 \frac{\text{mA}}{\text{s}} \\
4.0 \text{ s} \text{ to } 6.0 \text{ s} & \quad \frac{0.0 \text{ mA} - 4.0 \text{ mA}}{6.0 \text{ s} - 4.0 \text{ s}} = -2.0 \frac{\text{mA}}{\text{s}}
\end{align*} \]
7.0 s to 10.0 s

\[ \frac{-5.0 \text{ mA} - 0.0 \text{ mA}}{10.0 \text{ s} - 7.0 \text{ s}} = \frac{-5 \text{ mA}}{3 \text{ s}} \text{ or } -1.67 \frac{\text{mA}}{\text{s}} \]

**Voltage vs Time**

\[ E = (1.0 \text{mH}) \left( +2.0 \frac{\text{mA}}{\text{s}} \right) \]

\[ E = (1.0 \text{mH}) \left( +1.67 \frac{\text{mA}}{\text{s}} \right) \]
PERFORMANCE CHARACTERISTICS AND SCORING SCALE

Performance Characteristics
The following characteristics guide the scoring of responses to the written assignment.

<table>
<thead>
<tr>
<th>Purpose:</th>
<th>Fulfill the charge of the assignment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of Content:</td>
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</tr>
<tr>
<td>Support:</td>
<td>Support the response with appropriate examples and/or sound reasoning reflecting an understanding of the relevant knowledge and skills.</td>
</tr>
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</table>

Scoring Scale
Scores will be assigned to each response to the written assignment according to the following scoring scale.

<table>
<thead>
<tr>
<th>Score Point</th>
<th>Score Point Description</th>
</tr>
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</table>
| 4           | The "4" response reflects a thorough command of the relevant knowledge and skills.  
|             | • The response completely fulfills the purpose of the assignment by responding fully to the given task.  
|             | • The response demonstrates an accurate and highly effective application of the relevant knowledge and skills.  
|             | • The response provides strong support with high-quality, relevant examples and/or sound reasoning. |
| 3           | The "3" response reflects a general command of the relevant knowledge and skills.  
|             | • The response generally fulfills the purpose of the assignment by responding to the given task.  
|             | • The response demonstrates a generally accurate and effective application of the relevant knowledge and skills.  
|             | • The response provides support with some relevant examples and/or generally sound reasoning. |
| 2           | The "2" response reflects a partial command of the relevant knowledge and skills.  
|             | • The response partially fulfills the purpose of the assignment by responding in a limited way to the given task.  
|             | • The response demonstrates a limited, partially accurate and partially effective application of the relevant knowledge and skills.  
|             | • The response provides limited support with few examples and/or some flawed reasoning. |
| 1           | The "1" response reflects little or no command of the relevant knowledge and skills.  
|             | • The response fails to fulfill the purpose of the assignment.  
|             | • The response demonstrates a largely inaccurate and/or ineffective application of the relevant knowledge and skills.  
|             | • The response provides little or no support with few, if any, examples and/or seriously flawed reasoning. |
EVALUATION OF THE STRONG RESPONSE

This response is considered a strong response because it reflects a thorough command of relevant knowledge and skills.

Purpose. The candidate correctly describes how the net charge flowing through the inductor can be calculated based on the information provided in the graph \( I = dq/dt \rightarrow q = \int dq \) and correctly calculates the signed area under the curve from \( t = 0.0 \) s to \( 10.0 \) s. The result of the calculation is clearly stated in terms of the appropriate unit, millicoulombs \( (q = 0.5 \) mC\). In responding to the second part of the assignment, the candidate correctly states the relationship among current, voltage, and time, and concludes that the voltage across the inductor is equal to the product of the negative of the slope of the graph of current and the inductance, measured in millihenries \( (E = 1.0 \) mH \times -dI/dt\). The results of the calculation of voltage are correctly stated for each of the four separate time segments mentioned in the problem: \([0.0 \) s, \( 1.0 \) s\], \([2.0 \) s, \( 3.0 \) s\], \([4.0 \) s, \( 6.0 \) s\], \([7.0 \) s, \( 10.0 \) s\]. The graph of voltage as a function of time is correctly sketched and is appropriately labeled using appropriate scales and dimensions. Voltage is stated in terms of the correct dimensions of milliamperes per second \( (\text{mA/s})\).

Application of Content. Relevant content knowledge is applied throughout the response. The candidate correctly interprets scientific data presented in a graph and uses mathematics (e.g., the fundamental concepts of calculus) to analyze the data. The candidate relates the concept of an integral to the area under a curve and applies this concept to calculate the net charge by summing the areas of the triangular regions under the curve. The candidate links the concept of a derivative to the slope of each line segment and uses this link to create an effective graphic representation of the voltage across the inductor for each appropriate time segment from \( t = 0.0 \) s to \( t = 10.0 \) s.

Support. Sound reasoning is demonstrated throughout the response. The candidate uses the methods of elementary calculus and basic principles of electronics to draw valid conclusions from the given graph about the values of the electric charge through, and the electric voltage across, the inductor over the specified time intervals.