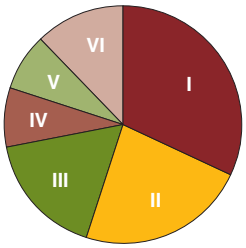
Physics: Content Knowledge (0265)

Test at a Glance

Test Name	**Physics: Content Knowledge**
Test Code	**0265**
Time	**2 hours**
Number of Questions	**100**
Format	**Multiple-choice questions; calculator use prohibited**



Content Categories		Approximate Number of Questions	Approximate Percentage of Questions
I.	Mechanics	32	32%
II.	Electricity and Magnetism	23	23%
III.	Optics and Waves	17	17%
IV.	Heat and Thermodynamics	8	8%
V.	Modern Physics, Atomic, and Nuclear Structure	8	8%
VI.	History and Nature of Science; Science Technology, and Social Perspectives (STS)	12	12%

About This Test

The Physics: Content Knowledge test is designed to measure the subject-area knowledge and competencies necessary for a beginning teacher of physics in a secondary school. The topics for questions are typically those covered in introductory college-level physics and physical science courses, although some questions of a more advanced nature are included, because secondary-school instructors must understand the subject matter from a more advanced viewpoint than that presented to their students. Also, since a major goal of science education is to have students develop an understanding of science and the impact of science and technology on the environment and human affairs, these areas are included in the assessment. The questions include definition of terms, comprehension of critical concepts, application, analysis, and problem solving.

This test may contain some questions that will not count toward your score.

The test consists of 100 multiple-choice questions that address examinees' breadth of knowledge in physics, embracing scientific principles, facts, methodology, and philosophy in the content areas of mechanics, electricity and magnetism, optics and waves, heat and thermodynamics, and modern physics, atomic and nuclear structure. Test takers have two hours to complete the test. The test is not intended to assess teaching skills but rather to demonstrate the candidate's fundamental knowledge in the major areas of physics.

Examinees will not need to use calculators in taking this test. The test book contains a periodic table and a table of information that presents various physical constants and a few conversion factors among SI units. Whenever necessary, additional values of physical constants are printed with the text of a question.

The test is designed to reflect current standards for knowledge, skills, and abilities in science education. Educational Testing Service (ETS) has aligned this test closely with the National Science Education Standards and works in collaboration with teacher educators, higher education content specialists, and accomplished practicing teachers in the field of physics to keep the test updated and representative of current standards.

In addition, the focus throughout the test on assessing conceptual understanding, critical thinking, and problem-solving in science reflects the national standard of "Unifying Concepts in Science."

Topics Covered

I. Mechanics

- Vectors
  - properties
  - addition and subtraction
  - multiplication
    - scalar (dot) product
    - vector (cross) product
- Kinematics
  - motion along a straight line
    - displacement
    - velocity
    - acceleration
  - motion in two dimensions
    - uniform circular motion
    - projectile motion
  - reference frames and relative motion
    - relative velocity
    - Galilean relativity
- Dynamics
  - force and Newton's laws of motion
    - Newton's first law
      - inertia
      - inertial reference frames
    - Newton's second law
      - force and acceleration
      - addition of forces (net force)
      - balanced versus unbalanced forces
    - Newton's third law
      - action-reaction forces
  - weight and mass
  - friction
    - static friction
    - kinetic friction
    - rolling friction
  - equilibrium of forces
  - equilibrium of moments (torques)
  - uniform circular motion
  - work, energy, and power
    - relationship between work and kinetic energy
    - work done by a variable force
  - conservation of energy
    - potential energy
    - conservative and nonconservative forces
  - simple harmonic motion and oscillations
    - Hooke's law
    - graphical and mathematical representations
    - energy considerations
    - pendulums
    - springs
  - linear momentum and impulse
    - momentum-impulse relationship
    - conservation of linear momentum

- elastic and inelastic collisions
- rigid body motion
  - angular velocity and angular acceleration
  - angular momentum, moment of inertia, torque, and center of mass
  - conservation of angular momentum
  - rotational kinetic energy
- mass-energy relationships
  - conservation of mass-energy
- Newton's law of universal gravitation and orbital motion
  - motion of satellites
  - Kepler's laws
    - law of orbits (first law)
    - law of areas (second law)
    - law of periods (third law)
- fluids
  - density and pressure
  - ideal fluids at rest
    - Pascal's law
    - Archimedes' principle
      - buoyant forces
  - ideal fluids in motion
    - Bernoulli's principle
      - streamlines
      - equation of continuity

II. Electricity and Magnetism

- Characteristics of static electricity, electric forces, and electric fields
  - electric forces and Coulomb's law
  - electric fields, Gauss's law, electric potential energy, electric potential, and potential difference
- Electric and magnetic properties of materials
  - conductors, insulators, and semiconductors
    - charging by friction, conduction and induction
  - capacitance and dielectrics
- Electric circuits, components, and applications
  - conductors, insulators, and semiconductors as used in circuits
  - sources of EMF
    - batteries, photocells, generators
  - current and resistance
    - Ohm's law
    - resistivity
  - capacitance and inductance
  - energy and power
  - analyzing circuits
    - series and parallel circuits using Ohm's law or Kirchhoff's rules
    - resistors and capacitors in series or parallel
    - internal resistance
    - RC circuits
  - power in alternating-current circuits
    - average power and energy transmission
  - measurement of potential difference, current, resistance, and capacitance
    - ammeter, galvanometer, voltmeter, and potentiometer
- Magnetic fields: causes, effects, and applications
  - magnets, magnetic fields, and magnetic forces
    - magnetic dipoles and materials
    - forces on a charged particle moving in a magnetic and/or electric field
      - Lorentz force law
      - cyclotron
      - mass spectrometer
    - forces or torques on current carrying conductors in magnetic fields
  - magnetic flux
    - Gauss's law of magnetism
  - magnetic fields produced by currents
    - Biot-Savart law
    - Ampere's law
      - magnetic field of a wire
      - magnetic field of a solenoid
      - displacement current
  - electromagnetic induction
    - magnetic flux
    - Lenz's law
    - Faraday's law
    - transformers, generators and motors

III. Optics and Waves

- Wave characteristics, phenomena, models and applications
  - speed, amplitude, wavelength, and frequency
  - inverse square law for intensity
  - reflection, refraction, absorption, transmission, and scattering
    - Snell's law
    - Rayleigh scattering
  - transverse and longitudinal waves and their properties
    - Doppler effect
    - resonance and natural frequencies
    - polarization
  - sound
    - pitch and loudness
    - air columns and standing waves
      - open at both ends
      - closed at one end
      - harmonics
    - beats
  - electromagnetic spectrum
    - frequency regions
    - color
  - principle of linear superposition and interference
    - diffraction, dispersion, beats and standing waves
    - interference in thin films and Young's double slit experiment
- Geometric Optics
  - reflection and refraction
    - Snell's law
    - total internal reflection
      - fiber optics
  - thin lenses
  - plane and spherical mirrors
  - prisms
  - optical instruments
    - simple magnifier
    - microscope
    - telescope

IV. Heat and Thermodynamics

- heat and temperature
  - measurement of heat and temperature
  - temperature scales
  - thermal expansion
  - thermocouples
  - heat capacity and specific heat
  - latent heat of phase change (heat of fusion, heat of vaporization)
- transfer of heat; conduction, convection, and radiation
- kinetic molecular theory
  - ideal gas laws
- laws of thermodynamics and thermodynamic processes
  - first law
    - internal energy
    - energy conservation
  - second law
    - entropy and disorder
    - reversible and irreversible processes
    - spontaneity
    - heat engines
      - Carnot cycle
      - efficiency
  - third law
    - absolute zero of temperature
  - Zeroth law
    - law of equilibrium
  - thermal processes involving pressure, volume, and temperature
- energy and energy transformations
  - kinetic, potential, mechanical, sound, magnetic, electrical, light, heat, nuclear, chemical

V. Modern Physics, Atomic and Nuclear Structure

- nature of the atom
  - Rutherford scattering
  - atomic models
    - Bohr model
  - atomic spectra

- atomic and nuclear structure
  - electrons, protons and neutrons
  - electron arrangement
  - isotopes
  - hydrogen atom energy levels
  - nuclear forces and binding energy
- radioactivity
  - radioactive decay
  - half life
  - isotopes
  - decay processes
    - alpha decay
    - beta decay
    - gamma decay
  - artificial radioactivity
- elementary particles
  - ionizing radiation
- organization of matter
  - elements, compounds, solutions, and mixtures
- physical properties of matter (phase changes, states of matter)
- nuclear energy
  - fission and fusion
  - nuclear reactions and their products
- special topics in modern physics
  - blackbody radiation
  - photoelectric effect
  - de Broglie's hypothesis
  - wave-particle duality
  - special relativity
    - Michelson-Morley experiment (ether and the speed of light)
    - simultaneity
    - Lorentz transformations
      - time dilation
      - length contraction
    - velocity addition

VI. History and Nature of Science; Science, Technology, and Social Perspectives (STS)

- Nature of Scientific Methodology, Inquiry, and Historical Perspectives
  - scientific method of inquiry
    - formulating problems
    - formulating and testing hypotheses
    - making observations
    - developing generalizations
  - science process skills
    - observing
    - hypothesizing
    - ordering
    - categorizing
    - comparing
    - inferring
    - applying
    - communicating
  - distinguish among hypotheses, assumptions, models, laws, and theories
  - experimental design
    - data collection
    - interpretation and presentation
    - significance of controls
    - integrate the overarching concepts of science
    - historical roots of the physical sciences and the contributions made by major historical figures to the physical sciences
    - scientific knowledge is subject to change
- Mathematics, Measurement, and Data Manipulation
  - scientific measurement and notation systems
  - processes involved in scientific data collection and manipulation
    - organization of data
    - significant figures
    - linear regression
  - interpret and draw conclusions from data, including those presented in tables, graphs, and charts
  - analyze errors in data that is presented
    - sources of error
    - accuracy
    - precision

- Laboratory Activities and Safety Procedures
  - safety procedures involved in the preparation, storage, use, and disposal of laboratory and field materials
  - identify appropriate use, calibration procedures, and maintenance procedures for laboratory and field equipment
  - preparation of reagents, materials, and apparatus for classroom use
  - knowledge of safety and emergency procedures for the science classroom and laboratory
  - knowledge of the legal responsibilities of the teacher in the science classroom
- STS
  - impact of science and technology on the environment and human affairs
  - issues associated with energy production, transmission, management, and use (including nuclear waste removal and transportation)
  - issues associated with the production, storage, use, management, and disposal of consumer products
  - issues associated with the management of natural resources
  - applications of science and technology in daily life
  - social, political, ethical, and economic issues arising from science and technology

Sample Test Questions

The sample questions that follow illustrate the kinds of questions in the test. They are not, however, representative of the entire scope of the test in either content or difficulty. Answers with explanations follow the questions.

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case.

1. Three resistors of 4 ohms each CANNOT be connected to give an equivalent resistance that is close to
   (A) 0.75 ohms
   (B) 2.66 ohms
   (C) 6 ohms
   (D) 12 ohms

2. A beam of light travels obliquely from one medium into another medium of higher index of refraction. All of the following are true statements about the beam of light EXCEPT:
   (A) Its speed increases.
   (B) Its wavelength decreases.
   (C) Its frequency remains the same.
   (D) It bends toward the normal.

3. Two satellites move in circular orbits around the Earth. The radius of the orbit of the outer satellite is three times the radius of the orbit of the inner satellite, as measured from the Earth's center. If the orbital speed of the inner satellite is v, then the orbital speed of the outer satellite is
   (A) $v/3$
   (B) $v/\sqrt{3}$
   (C) $\sqrt{3} \cdot v$
   (D) $3v$

4. Which of the following is an example of the Doppler effect?
   (A) Sudden increase in pitch when a moving sound source is moving away from a listener
   (B) Sudden increase in pitch when a moving listener is moving away from a sound source
   (C) Sudden drop in pitch as a moving sound source passes a listener
   (D) Continuous drop in pitch as a moving sound source approaches a listener

5. Supplies appropriate for the measurement in a school laboratory of the density of a small rock sample include all of the following EXCEPT
   (A) water
   (B) a graduated cylinder
   (C) a platform balance
   (D) a thermometer

6. Which of the following properties of a substance depends on the amount of the sample?
   (A) Temperature
   (B) Half-life
   (C) Density
   (D) Inertia

7. $n \longrightarrow p + e^- + \bar{\nu}$
   A nucleus can emit a negative beta particle according to the reaction above, where n = neutron, p = proton, e^- = electron, and $\bar{\nu}$ = antineutrino. Which of the following best states the information in this reaction?
   (A) A neutron is composed of an electron and a proton.
   (B) The mass of a neutron is equal to the mass of a proton plus the mass of an electron.
   (C) Since a neutrino has no rest mass or charge, a neutron may decay into a proton and an electron.
   (D) The mass of a neutron is greater than the mass of a proton plus the mass of an electron.

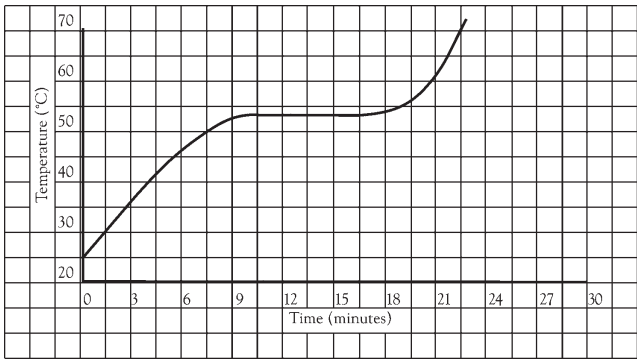
8. Faraday's law of electromagnetic induction describes how an electric field can be produced at a point in space by

   (A) an electric charge

   (B) a constant magnetic field

   (C) a changing magnetic field

   (D) a steady current

9. 

   A sample of a pure solid substance is heated at a constant rate and its temperature recorded as a function of time. A graph of the data is shown above. At about what temperature is the heat added being used to melt the substance?

   (A) 25°C

   (B) 41°C

   (C) 53°C

   (D) 60°C

10. If electrons have a velocity of 4.0×10^6 meters per second at right angles to a magnetic field of 0.20 newton per ampere-meter, what is the magnitude of the force on a single electron?

    (A) 1.3×10^{-13} N

    (B) 1.6×10^{-14} N

    (C) 6.4×10^{-19} N

    (D) 3.2×10^{-26} N

Questions 11–12 refer to the following statements.

A mass is suspended from a vertical spring and displaced downward a distance *Y* from its equilibrium position. After being released, it oscillates with period *T*.

11. At a time $5T/4$, the velocity of the mass is

    (A) a maximum and directed upward

    (B) a maximum and directed downward

    (C) constant

    (D) zero

12. At a time $5T/4$, the acceleration of the mass is

    (A) a maximum and directed upward

    (B) a maximum and directed downward

    (C) constant

    (D) zero

13. In a test of an automobile air bag, a mannequin with a mass of 70 kilograms hits a stationary air bag. The velocity of the mannequin at the instant of impact is 25 meters per second. After 0.25 seconds the mannequin has come to a complete stop and the air bag has deflated. The average force on the mannequin during this interval is most nearly

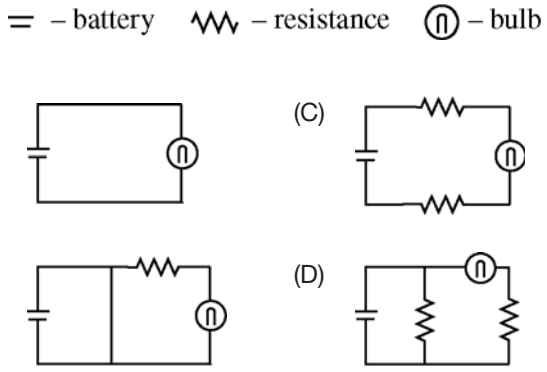
    (A) 70 N

    (B) 700 N

    (C) 7,000 N

    (D) 70,000 N

14. In which of the following is the battery short-circuited?



15. Polarized sunglasses are used to cut glare from sunlight reflected at a glancing angle off cars, water, and other surfaces. Such sunglasses are a practical application of which of the following physical principles?

    (A) Brewster's law

    (B) Lenz's law

    (C) Coulomb's law

    (D) Snell's law

16. A thin ring of mass 50 g and radius 5.0 cm is spinning at a frequency of 6.0 rev/s. Mass is added uniformly to the ring until it has a final mass of 75 g. What is the final spinning frequency of the ring?

    (A) 0 rev/s

    (B) 4 rev/s

    (C) 6 rev/s

    (D) 8 rev/s

17. A washer consists of a 3.00 cm diameter circle of sheet metal with a 1.00 cm diameter circular hole in the middle. If the metal washer is heated until the diameter of the washer is 3.03 cm, then the diameter of the hole will be

    (A) 0.97 cm

    (B) 0.99 cm

    (C) 1.00 cm

    (D) 1.01 cm

18. In a particle accelerator, it becomes increasingly difficult to increase a particle's speed because of

    (A) relativistic mass increase

    (B) time dilation

    (C) length contraction

    (D) inelastic collisions

19. The true length of a block of wood is 1.010 cm. Three measurements of this block produced the following values: 1.4 cm, 1.2 cm, and 0.9 cm. Which of the following statements is true concerning these measurements?

    (A) They are precise and accurate.

    (B) They are precise but not accurate.

    (C) They are accurate but not precise.

    (D) They are neither precise nor accurate.

20. Which of the following items will be attracted to the north pole of a permanent magnet by a magnetic force?

    (A) The north pole of another permanent magnet

    (B) A piece of iron that is not a permanent magnet

    (C) A positively charged glass rod

    (D) A negatively charged rubber rod

Answers

1. There are four possible series and parallel combinations involving three resistors of equal value. The following table lists these combinations along with their corresponding equivalent resistances.

COMBINATION	*REQ*
3 in series	12 Ω
3 in parallel	1.33 Ω
2 series, 1 parallel	2.66 Ω
1 series, 2 parallel	6.0 Ω

Thus, A is the correct answer.

2. According to Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, and when $n_2 > n_1$ then $\theta_2 < \theta_1$; that is, the beam bends toward the normal, so choice D is true. The frequency of the light will remain unchanged. Thus, choice C is true. The speeds v_1 and v_2 of the light in the two media are c/n_1 and c/n_2, respectively. Thus $v_2 < v_1$ for $n_2 > n_1$, and since the frequency remains the same, the wavelength decreases. That is, $\lambda_2 < \lambda_1$, so choice B is true. Finally, $v_2 < v_1$ indicates that choice A is false. Because A is false, it is the correct answer.

3. For circular orbital motion in a gravitational field, $\frac{v^2}{R} = \frac{GM}{R^2}$ which gives $v^2 = \frac{GM}{R}$.

Thus, letting v_i, R_i denote the velocity and radius of the orbit of the inner satellite and v_o, R_o the velocity and the radius of the orbit of the outer satellite, one has

$$\left[\frac{v_o}{v_i}\right]^2 = \frac{R_i}{R_o}, \text{ or } v_o = v\sqrt{\frac{R_i}{R_o}} = \frac{v}{\sqrt{3}} \text{ since } v_i = v.$$

This gives B as the correct answer.

4. Choices A, B, and D are NOT true of the Doppler effect. Choice C is true. For a sound wave of speed v and a sound source moving toward a listener at speed u, the frequency ν' heard by the listener is given by

$$\nu' = \nu\left(\frac{v}{v-u}\right)$$

where u is the frequency of the source. As the source passes and moves away from the listener, the frequency ν' is given by

$$\nu' = \nu\left(\frac{v}{v+u}\right)$$

Thus, the frequency drops as the source passes and then moves away from the listener.

5. The density of a rock is subject to very small variations with temperature, so the thermometer is not important. The other pieces of equipment are needed for the determination since density is mass per unit volume. The correct answer is D.

6. Inertia is a property of a substance, proportional to its mass, and therefore depends on the amount of the sample. The correct answer is D.

7. The antineutrino, though massless, carries energy. Thus, the mass of a neutron must be greater than the mass of a proton plus the mass of an electron. In fact,

mass(n) – mass($p + e^- + \nu$) = mass(n) – mass($p + e^-$) ≈ 0.77 MeV.

Thus, D is the correct answer.

8. Choice C is the correct answer. For circuits, Faraday's law of electromagnetic induction states that the induced electromotive force in a circuit is equal to the rate of change of the magnetic flux through it. In general, Faraday's law relates an electric field in vacuum to the rate of change of a magnetic field. In differential form, the relation is clearly seen:

$$\nabla \times \mathbf{E} = -\frac{\partial B}{\partial t}$$

9. When a substance is heated, its temperature increases unless it is undergoing a phase change. During melting, the temperature remains constant since the energy absorbed is being used to do work against the attractive forces in becoming liquid particles. In the diagram, melting begins around 9 minutes and a temperature around 53°C. The correct answer is C.

10. According to the Lorentz force law,

$F = qvB = (1.6 \times 10^{-19}\text{C})\ (4.0 \times 10^{6}\ \text{m/s})\ (0.20\ \text{N/Am}) = 1.3 \times 10^{-13}\ \text{N}$

Thus, A is the correct answer.

11. At 5*T*/4, the mass is situated midway between its highest and lowest positions; it is moving upward and has its maximum speed. Thus, A is the correct answer.

12. At 5*T*/4, the mass is situated midway between its highest and lowest positions. At this position, the sum of the two forces acting on the mass is zero; thus its acceleration is zero and D is the correct answer.

13. The average force $\bar{F}$ is equal in magnitude to the change in the momentum of the mannequin divided by the elapsed time, or

$$\bar{F} = \frac{m\Delta V}{\Delta t} = \frac{(70\text{ kg})(25\text{ m/s})}{0.25\text{ s}} = 7{,}000\text{ N}.$$

Thus, C is the correct answer.

14. The correct answer is (B). In this diagram the path of the circuit is such that current will be diverted from passing through the resistor and the bulb. When the part of a circuit with the most resistance is bypassed, and all of the current flows through the part with zero (negligible) resistance, a short circuit is said to exist.

15. The correct answer is A. According to Brewster's law, reflected light will always be polarized in a horizontal direction, parallel to the reflecting surface. Polarized sunglasses are constructed to block this reflected light and to transmit light polarized only in the vertical direction.

16. The correct answer is B. The additional mass is added uniformly to the ring, which means that no external torques act on the system and angular momentum is conserved. Now, the angular momentum is equal to the product of the ring's mass, the ring's angular velocity, and the square of the ring's radius. Because the radius is also constant, conservation of angular momentum gives (50 g) x (6.0 rev/s) = (75 g) x (final angular frequency), or final angular frequency = 4 rev/s.

17. The correct answer is D. At a given radius, the linear expansion is the same in all radial directions and is equal to the product of the radius, the thermal expansion coefficient, and the temperature change. Thus, the expansion of the inner diameter will be equal to one-third the expansion of the outer diameter, or 0.01 cm, for a total internal diameter of 1.01 cm.

18. The correct answer is A. In a particle accelerator, the particles are accelerated to relativistic speeds. According to the theory of special relativity, a particle's mass (inertia) increases as the particle's speed increases. Thus, greater and greater forces are needed to accelerate the particle as its speed increases.

19. The correct answer is D. The measurements differ from the true length by 0.39 cm, 0.19 cm, and -0.11 cm. Thus, the measurements are quite different in value from the true value, which means that they are not accurate. The measurements are also quite different in value from one another (not repeatable), which means that they are not precise.

20. The correct answer is B. Iron is easily magnetized. When iron is brought close to a permanent magnet, the iron will become magnetized in such a way as to be attracted to the permanent magnet.

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