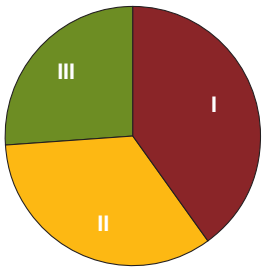
Physics: Content Knowledge (0261)

Test at a Glance

Test Name	**Physics: Content Knowledge**
Test Code	**0261**
Time	**1 hour**
Number of Questions	**50**
Format	**Multiple-choice questions; calculator use prohibited**



Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
I. Mechanics	20	40%
II. Electricity and Magnetism	17	34%
III. Optics and Waves; Special Topics in Modern Physics	13	26%

About This Test

The Physics: Content Knowledge test measures the knowledge and competencies necessary for a beginning teacher of physics in a secondary school. Examinees have typically completed or nearly completed a bachelor's degree program in physics, with appropriate coursework in education.

The 50 multiple-choice questions 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, and special topics in modern physics.

Topics are typically covered in an introductory college-level physics course, although some questions of a more advanced nature are included since secondary school instructors must understand the subject matter from a more advanced viewpoint than that presented to their students.

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

Examinees are not permitted to use calculators in taking this test; the test books contain 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 the question.

Topics Covered

Representative descriptions of topics covered in each category are provided below.

I. Mechanics

- Vectors
- Kinematics: straight line motion, projectile motion, circular motion, periodic motion, reference frames, and relative velocity
- Dynamics:
  - Newton's laws of motion
  - weight versus mass
  - statics
  - simple harmonic motion, oscillations, and springs
  - friction
  - conservative forces and potential energy
  - work, energy, and power
  - momentum and the impulse-momentum principle
  - concepts of rigid body motion
  - elastic and inelastic collisions
  - conservation laws involving energy, momentum, angular momentum, and mass-energy
  - Newton's law of universal gravitation
  - orbital motion and the motion of satellites
- Fluid mechanics: Pascal's principle, Archimedes' principle, Bernoulli's principle

II. Electricity and Magnetism

- Characteristics of static electricity, electric forces, and electric fields: Coulomb's law, Gauss's law, electric potential energy, electric potential, and potential difference
- Electric and magnetic properties of materials: conductors, semiconductors, and insulators
- Circuits, components, and applications:
  - conductors, semiconductors, and insulators
  - current, resistance, capacitance, and inductance
  - series and parallel circuits
  - alternating current circuits
  - measurement of potential difference, current, resistance, and capacitance
  - sources of EMF such as batteries, photocells, and generators
- Magnetic fields, causes, effects, and applications:
  - magnets, magnetic fields, and magnetic forces
  - magnetic flux
  - Biot-Savart law and Ampere's law
  - Faraday's and Lenz's laws of electromagnetic induction
  - transformers and motors
  - Lorentz force law and applications

III. Optics and Waves; Special Topics in Modern Physics

- Wave characteristics: speed, amplitude, wavelength, frequency, inverse square law for intensity
- Transverse and longitudinal waves and their properties
- Phenomena, models, and applications:
  - reflection
  - refraction and Snell's law
  - absorption, transmission, and scattering
  - superposition of waves, interference, and standing waves
  - diffraction
  - dispersion
  - resonance and natural frequencies
  - Doppler effect
- Light and sound:
  - characteristics of sound waves
  - air columns and strings
  - electromagnetic spectrum
  - color
  - geometric optics
  - polarization
- Modern physics:
  - blackbody radiation
  - photoelectric effect
  - Michelson-Morley experiment
  - de Broglie's hypothesis
  - wave-particle duality
  - nuclear forces and binding energy
  - artificial and natural radioactivity
  - special relativity

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) $\sqrt{3}$

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

Questions 5–6 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.

5. 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

6. 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

7. $n \rightarrow p + e^{-} + \bar{v}$

   A nucleus can emit a negative beta particle according to the reaction above, where $n =$ neutron, $p =$ proton, $e^{-} =$ electron, and $\bar{v} =$ 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. 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

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

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. At $5T/4$, 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.

6. At $5T/4$, 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.

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,

$\text{mass}(n) - \text{mass}(p + e^- + \bar{\nu}) = \text{mass}(n) - \text{mass}(p + e^-) \approx 0.77$ 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:

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

9. 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.

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.

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