

THE TWENTY-SECOND ANNUAL SLAPT PHYSICS CONTEST
SOUTHERN ILLINOIS UNIVERSITY EDWARDSVILLE
APRIL 21, 2007

SENIOR PHYSICS TEST

$$g = 9.8 \text{ m/s/s}$$

$$c = 3 \times 10^8 \text{ m/s}$$

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$m \text{ (electron)} = 9.11 \times 10^{-31} \text{ kg}$$

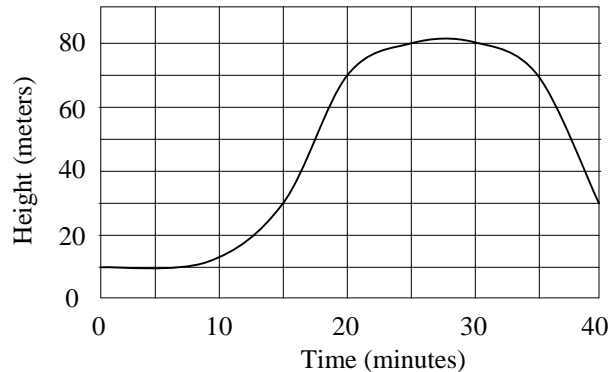
$$k \text{ (electric)} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

Please answer the following questions on the supplied answer sheet. You may write on this test booklet and keep it for your records. Only the answer sheets will be scored.

- Complete the following statement: An inertial reference frame is one in which
 - Newton's first law of motion is valid.
 - the inertias of objects within the frame are zero.
 - the frame is accelerating.
 - the acceleration due to gravity is greater than zero m/s^2 .
 - Newton's third law of motion is not valid.
- The position of a particle moving along the x axis is given by $x = 6.0t^2 - 1.0t^3$, where x is in meters and t in seconds. What is the position of the particle when it achieves its maximum speed in the positive x direction?
 - 24 m
 - 12 m
 - 32 m
 - 16 m
 - 2.0 m
- An eagle is flying due east at 8.9 m/s carrying a gopher in its talons. The gopher manages to break free at a height of 12 m. What is the magnitude of the gopher's velocity as it reaches the ground? Note: effects of air resistance are not included in this calculation.

| | | |
|------------|-------------|-------------|
| (a) 22 m/s | (c) 11 m/s | (e) 8.9 m/s |
| (b) 18 m/s | (d) 9.8 m/s | |

- The graph shows the height versus time of an object. Estimate the instantaneous velocity, in m/s, of the object at time $t = 15$ min.
 - 0.90 m/s
 - 0.70 m/s
 - 0.50 m/s
 - 0.30 m/s
 - 0.10 m/s



- The velocity at the midway point of a ball able to reach a height y when thrown with velocity v_0 at the origin is:

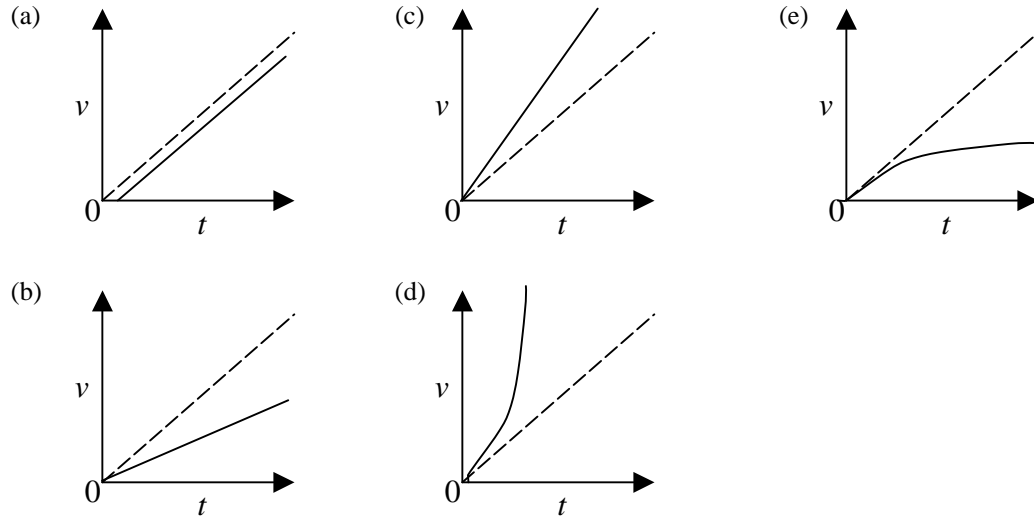
| | | | | |
|--------------------|-------------------------|-----------------------------|-------------------------|---------|
| a. $\frac{v_0}{2}$ | b. $\sqrt{v_0^2 - 2gy}$ | c. $\sqrt{\frac{v_0^2}{2}}$ | d. $\sqrt{v_0^2 + 2gy}$ | e. gy |
|--------------------|-------------------------|-----------------------------|-------------------------|---------|
- An apple crate with a weight of 225 N accelerates along a *frictionless* surface as the crate is pulled with a force of 14.5 N as shown in the drawing. What is the horizontal acceleration of the crate?

| | | |
|---------------------------|---------------------------|---------------------------|
| (a) 1.40 m/s^2 | (c) 1.29 m/s^2 | (e) 0.644 m/s^2 |
| (b) 0.427 m/s^2 | (d) 0.597 m/s^2 | |

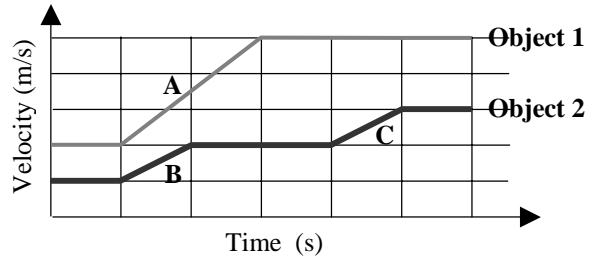
7. If the same object were released in air, the magnitude of its acceleration would begin at the free-fall value, but it would decrease continuously to zero as the object continued to fall.

For which one of the choices given does the solid line best represent the speed of the object as a function of time when it is dropped from rest in air?

Note: The dashed line shows the free-fall under vacuum graph for comparison.

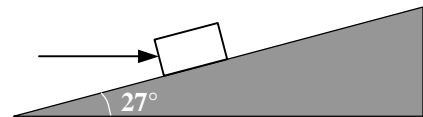


8. The graph shows the velocities of two objects of equal mass as a function of time. Net forces F_A , F_B , and F_C acted on the objects during intervals A, B, and C, respectively. Which one of the following choices is the correct relationship between the magnitudes of the net forces?



- (a) $F_B = F_C > F_A$ (c) $F_A > F_B = F_C$ (e) $F_A > F_B > F_C$
 (b) $F_C > F_B > F_A$ (d) $F_A = F_B = F_C$

9. A 250-N force is directed horizontally as shown to push a 29-kg box up an inclined plane at a constant speed. Determine the magnitude of the normal force, F_N , and the coefficient of kinetic friction, μ_k .



- | | F_N | μ_k |
|-----|-------|---------|
| (a) | 330 N | 0.31 |
| (b) | 310 N | 0.33 |
| (c) | 250 N | 0.27 |
| (d) | 290 N | 0.30 |
| (e) | 370 N | 0.26 |

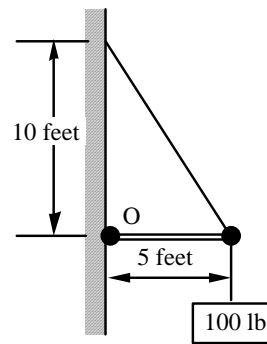
10. An astronaut orbits the earth in a space capsule whose height above the earth is equal to the earth's radius. How does the weight of the astronaut in the capsule compare to her weight on the earth?
- Her weight is equal to her weight on earth.
 - Her weight is equal to one-fourth her weight on earth.
 - Her weight is equal to one-half of her weight on earth.
 - Her weight is equal to one-third of her weight on earth.
 - Her weight is equal to zero.

11. A force acting on an object moving along the x axis is given by

$$F_x = (14x - 3.0x^2) \text{ N}$$

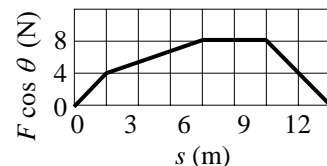
where x is in m. How much work is done by this force as the object moves from $x = -1$ m to $x = +2$ m?

- +12 J
 - +28 J
 - +40 J
 - +42 J
 - 28 J
12. A massless horizontal strut is attached to the wall at the hinge O. Which one of the following phrases best describes the force that the hinge pin applies to the strut if the weight of the cables is also neglected?
- 50 lb, to the right
 - 100 lb, straight up
 - 200 lb, to the right
 - 244 lb, 27° above the strut
 - 56 lb, to the left



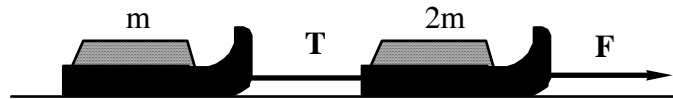
13. A 51-kg woman runs up a flight of stairs in 5.0 s. Her net upward displacement is 5.0 m. Approximately, what average power did the woman exert while she was running?
- 5.0 kW
 - 1.0 kW
 - 0.75 kW
 - 0.50 kW
 - 0.25 kW

14. The force component acting on an object along the displacement varies with the displacement s as shown in the graph. Determine the work done on the object as it travels from $s = 0.0$ to 12 m.
- 48 J
 - 66 J
 - 72 J
 - 57 J
 - 81 J



15. Sara puts a box into the trunk of her car. Later, she drives around an unbanked curve that has a radius of 48 m. The speed of the car on the curve is 16 m/s, but the box remains stationary relative to the floor of the trunk. Determine the minimum coefficient of static friction for the box on the floor of the trunk.
- (a) 0.42 (d) 0.33
 (b) 0.54 (e) This cannot be determined without knowing the mass of the box.
 (c) 0.17

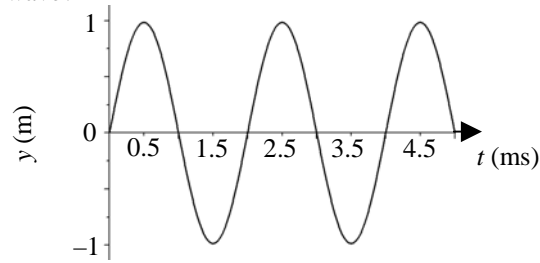
16. Two sleds are hooked together in tandem as shown in the figure. The front sled is twice as massive as the rear sled.



- The sleds are pulled along a frictionless surface by an applied force **F**. The tension in the rope between the sleds is **T**. Determine the ratio of the magnitudes of the two forces, $\frac{T}{F}$.
- (a) 0.25 (c) 0.50 (e) 2.0
 (b) 0.33 (d) 0.67
17. A certain crane can provide a maximum lifting force of 25 000 N. It hoists a 2000-kg load starting at ground level by applying the maximum force for a 2-second interval; then, it applies just sufficient force to keep the load moving upward at constant speed. Approximately how long does it take to raise the load from ground level to a height of 30 m?
- (a) 2 s (c) 7 s (e) 10 s
 (b) 5 s (d) 9 s
18. A horizontal plank ($m = 2.0$ kg, $L = 1.0$ m) is pivoted at one end. A spring ($k = 1.0 \times 10^3$ N/m) is attached at the other end, as shown in the figure. Find the angular frequency (in rad/s) for small oscillations.

- a. 39
 b. 44
 c. 55
 d. 66
 e. 25

19. The speed of sound in a certain metal block is 3.00×10^3 m/s. The graph shows the amplitude (in meters) of a wave traveling through the block versus time (in milliseconds). What is the wavelength of this wave?



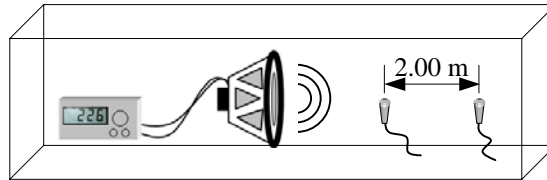
- (a) 0.5 m (c) 3.0 m (e) 6.0 m
 (b) 2.0 m (d) 4.0 m
20. A certain string on a piano is tuned to produce middle C ($f = 261.63$ Hz) by carefully adjusting the tension in the string. For a fixed wavelength, what is the frequency when this tension is doubled?
- (a) 130.08 Hz (c) 370.00 Hz (e) 523.26 Hz
 (b) 185.00 Hz (d) 446.63 Hz
21. A wave has an amplitude of 0.35 m, a frequency of 1.05×10^6 Hz, and travels in the positive x direction at the speed of light, 3.00×10^8 m/s. Which one of the following equations correctly represents this wave?
- (a) $y = 0.35 \sin (6.60 \times 10^6 t - 0.022x)$ (d) $y = 0.35 \sin (286t + 1.05 \times 10^6 x)$
 (b) $y = 0.35 \sin (6.60 \times 10^6 t + 0.022x)$ (e) $y = 0.35 \sin (1.05 \times 10^6 t + 3.00 \times 10^8 x)$
 (c) $y = 0.35 \sin (286t - 1.05 \times 10^6 x)$

Questions 22 and 23 pertain to the situation described below:

A periodic transverse wave is established on a string such that there are exactly two cycles traveling along a 3.0-m section of the string. The crests move at 20.0 m/s.

22. How long does it take a particle at the top of a crest to reach the bottom of an adjacent trough?
- (a) 0.018 s (c) 0.075 s (e) 0.30 s
 (b) 0.038 s (d) 0.150 s
23. How could the speed of the wave be increased?
- (a) by increasing the period (d) by increasing the tension in the string
 (b) by decreasing the amplitude (e) by increasing amplitude
 (c) by decreasing the frequency
24. A bell is ringing inside of a sealed glass jar that is connected to a vacuum pump. Initially, the jar is filled with air. What does one hear as the air is slowly removed from the jar by the pump?
- (a) The sound intensity from the bell gradually decreases.
 (b) The frequency of the sound from the bell gradually increases.
 (c) The frequency of the sound from the bell gradually decreases.
 (d) The speed of the sound from the bell gradually increases.
 (e) The intensity of the sound from the bell does not change.

25. The speaker and two microphones shown in the figure are arranged inside a sealed container filled with neon gas. The wires from the microphones are connected to an oscilloscope (not shown). The signal from the microphones is monitored beginning at time $t = 0$ s when a sound pulse is emitted from the speaker. The pulse is picked up by microphone 1 at $t_1 = 1.150 \times 10^{-2}$ s and by microphone 2 at $t_2 = 1.610 \times 10^{-2}$ s. What is the speed of sound in neon gas?



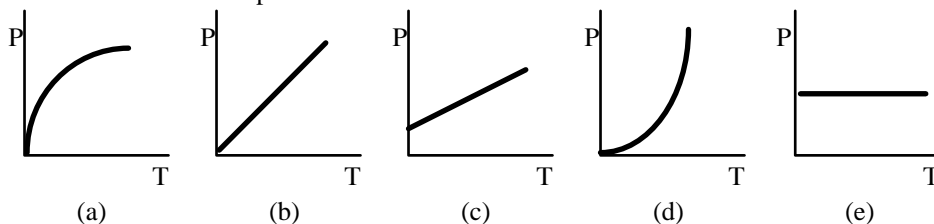
- (a) 124 m/s
 (b) 174 m/s
 (c) 362 m/s
 (d) 435 m/s
 (e) 724 m/s
26. Two boys are whispering in the library. The radiated sound power from one boy's mouth is 1.2×10^{-9} W; and it spreads out uniformly in all directions. What is the minimum distance the boys must be away from the librarian so that she will not be able to hear them? The threshold of hearing for the librarian is 1.00×10^{-12} W/m².
- (a) 100 m
 (b) 35 m
 (c) 23 m
 (d) 16 m
 (e) 9.8 m

27. A column of water of height 70.0 cm supports a column of an unknown liquid as suggested in the figure (not drawn to scale). Assume that both liquids are at rest and that the density of water is 1.0×10^3 kg/m³.

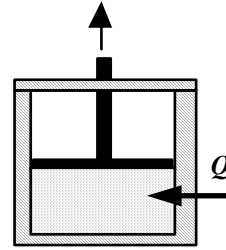


- Determine the density of the unknown liquid.
- (a) 3.9×10^2 kg/m³
 (b) 1.2×10^3 kg/m³
 (c) 2.6×10^3 kg/m³
 (d) 3.3×10^3 kg/m³
 (e) 3.9×10^3 kg/m³
28. Which one of the following statements best explains why convection does not occur in solids?
- (a) Molecules in a solid are more closely spaced than in a gas.
 (b) The molecules in a solid are not free to move throughout the volume of the solid.
 (c) Molecules in a solid vibrate at a lower frequency than those in a liquid.
 (d) Solids are more compressible than liquids.
 (e) Solids are less compressible than gases.

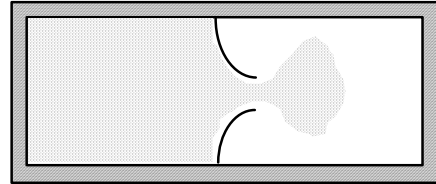
29. Which one of the following graphs shows the rate at which heat is emitted from a hot body as a function of its Kelvin temperature T ?



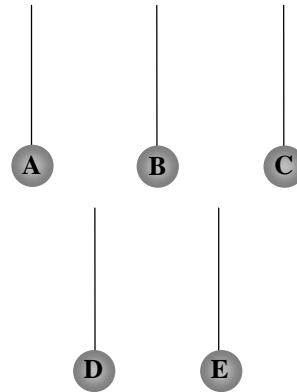
30. When the gas enclosed beneath the piston shown in the figure receives 1930 J of heat, Q , from its surroundings, it performs 2250 J of work in raising the piston. What is the change in the internal energy of the gas?
- (a) -320 J
 (b) $+320$ J
 (c) -4180 J
 (d) $+4180$ J
 (e) zero joules



31. A thermally isolated sample of an ideal gas at a fixed temperature is confined to one half of a container by an impermeable membrane. The other half of the container is evacuated. The membrane is then pierced and the gas is allowed to expand freely and to double its volume as shown. Which one of the following statements is true concerning this situation?
- (a) The process is reversible.
 (b) This is an isothermal process.
 (c) The entropy of the gas decreases.
 (d) The internal energy of the gas must decrease.
 (e) The temperature of the gas decreases to one-half of its original value.



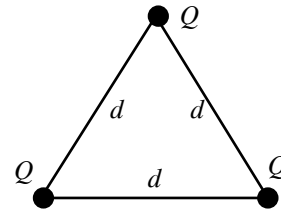
32. Five styrofoam balls are suspended from insulating threads. Several experiments are performed on the balls; and the following observations are made:
- I. Ball A attracts B and A repels C.
 II. Ball D attracts B and D has no effect on E.
 III. A negatively charged rod attracts both A and E.
- What are the charges, *if any*, on *each* ball?



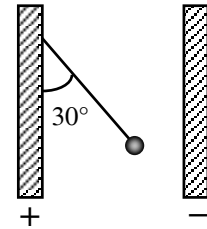
| | A | B | C | D | E |
|-----|----------|----------|----------|----------|----------|
| (a) | + | - | + | 0 | + |
| (b) | + | - | + | + | 0 |
| (c) | + | - | + | 0 | 0 |
| (d) | - | + | - | 0 | 0 |
| (e) | + | 0 | - | + | 0 |

33. A charge Q exerts a 12 N force on another charge q . If the distance between the charges is doubled, what is the magnitude of the force exerted on Q by q ?
- (a) 3 N
 (b) 6 N
 (c) 24 N
 (d) 36 N
 (e) 48 N

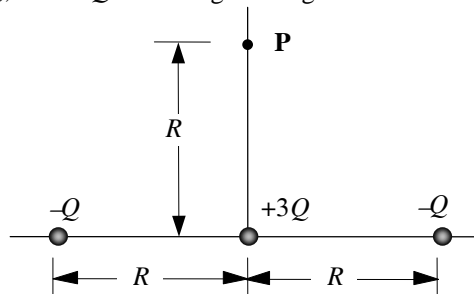
- 34 Three identical point charges, Q , are placed at the vertices of an equilateral triangle as shown in the figure. The length of each side of the triangle is d . Determine the magnitude and direction of the total electrostatic force on the charge at the top of the triangle.



- (a) $\frac{Q^2\sqrt{3}}{4\pi\epsilon_0 d^2}$, directed upward
 (b) $\frac{Q^2\sqrt{3}}{4\pi\epsilon_0 d^2}$, directed downward
 (c) $\frac{Q^2}{2\pi\epsilon_0 d^2}$, directed upward
 (d) $\frac{Q^2}{2\pi\epsilon_0 d^2}$, directed downward
 (e) zero
- 35 A small sphere of mass 1.0×10^{-6} kg carries a total charge of 2.0×10^{-8} C. The sphere hangs from a silk thread between two large parallel conducting plates. The excess charge on each plate is equal in magnitude, but opposite in sign. If the thread makes an angle of 30° with the positive plate as shown, what is the magnitude of the charge density on each plate?



- (a) 2.5×10^{-9} C/m²
 (b) 5.2×10^{-9} C/m²
 (c) 1.0×10^{-9} C/m²
 (d) 2.1×10^{-8} C/m²
 (e) 4.2×10^{-8} C/m²
- 36 Three point charges $-Q$, $-Q$, and $+3Q$ are arranged along a line as shown in the sketch.



What is the electric potential at the point P?

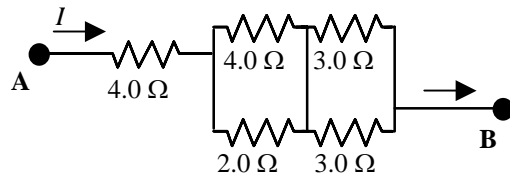
- (a) $+kQ/R$
 (b) $-2kQ/R$
 (c) $-1.6kQ/R$
 (d) $+1.6kQ/R$
 (e) $+4.4kQ/R$
- 37 How many electrons flow through a battery that delivers a current of 3.0 A for 12 s?
- (a) 4
 (b) 36
 (c) 4.8×10^{15}
 (d) 6.4×10^{18}
 (e) 2.2×10^{20}

38. A physics student performed an experiment in which the potential difference V between the ends of a long straight wire was varied. The current I in the wire was measured at each value of the potential difference with an ammeter and the results of the experiment are shown in the table.

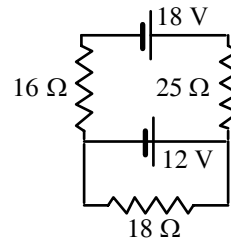
| <i>Trial</i> | <i>V (volts)</i> | <i>I (amperes)</i> |
|--------------|------------------|--------------------|
| 1 | 5.0 | 0.25 |
| 2 | 10.0 | 0.50 |
| 3 | 15.0 | 0.75 |
| 4 | 20.0 | 1.00 |
| 5 | 25.0 | 1.50 |
| 6 | 30.0 | 1.65 |
| 7 | 35.0 | 1.55 |
| 8 | 40.0 | 1.53 |

Which one of the following statements is the *best* conclusion based on the data?

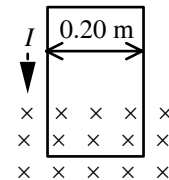
- (a) The resistance of the wire is $20\ \Omega$.
 (b) The wire does not obey Ohm's law.
 (c) The current in the wire is directly proportional to the applied potential difference.
 (d) The wire obeys Ohm's law over the range of potential differences between 5 and 30 V.
 (e) The wire obeys Ohm's law over the range of potential differences between 5 and 20 V.
39. Five resistors are connected as shown. What is the equivalent resistance between points **A** and **B**?
- (a) $6.8\ \Omega$ (d) $2.1\ \Omega$
 (b) $9.2\ \Omega$ (e) $16\ \Omega$
 (c) $3.4\ \Omega$



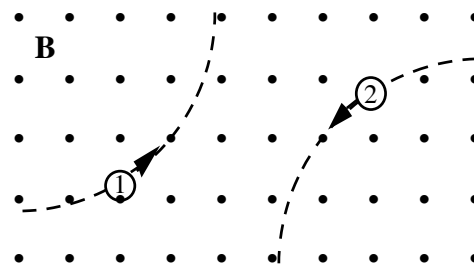
40. Three resistors and two batteries are connected as shown in the circuit diagram. What is the magnitude of the current through the 12-V battery?
- (a) 0.15 A
 (b) 0.82 A
 (c) 0.30 A
 (d) 0.67 A
 (e) 0.52 A



41. A loop of wire with a weight of 1.47 N is oriented vertically and carries a current $I = 1.75\ \text{A}$. A segment of the wire passes through a magnetic field directed into the plane of the page as shown. The net force on the wire is measured using a balance and found to be zero. What is the magnitude of the magnetic field?
- (a) zero tesla (d) 1.5 T
 (b) 0.51 T (e) 4.2 T
 (c) 0.84 T



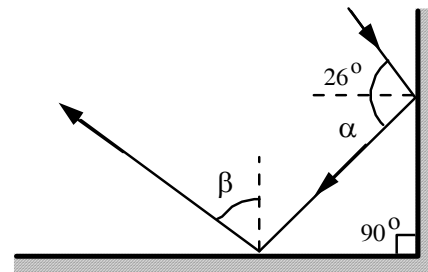
42. Two particles move through a uniform magnetic field that is directed out of the plane of the page. The figure shows the paths taken by the two particles as they move through the field. The particles are not subject to any other forces or fields. Which one of the following statements concerning these particles is true?
- (a) The particles may both be neutral.
 (b) Particle 1 is positively charged; 2 is negative.
 (c) Particle 1 is positively charged; 2 is positive.
 (d) Particle 1 is negatively charged; 2 is negative.
 (e) Particle 1 is negatively charged; 2 is positive.



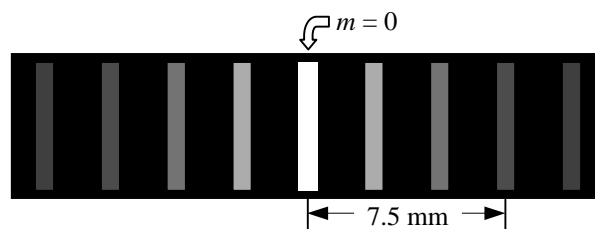
43. The bending of light as it moves from one medium to another with differing indices of refraction is due to a change in what property of the light?
- (a) amplitude (c) frequency (e) color
 (b) period (d) speed

44. A ray of light is reflected from two plane mirror surfaces as shown in the figure. What are the correct values of α and β ?

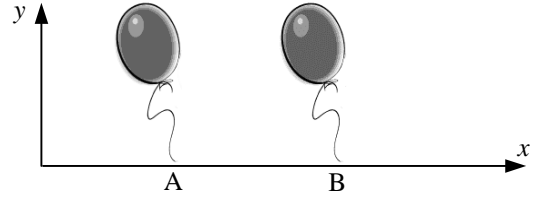
| | Value of α | Value of β |
|-----|-------------------|------------------|
| (a) | 26° | 26° |
| (b) | 26° | 64° |
| (c) | 38° | 52° |
| (d) | 52° | 26° |
| (e) | 64° | 26° |



45. When certain light rays pass from a vacuum into a block of an unknown material, the measured index of refraction of the material is 3.50. What is the speed of light inside the block?
- (a) 1.0×10^7 m/s (c) 8.6×10^7 m/s (e) 2.9×10^8 m/s
 (b) 4.8×10^7 m/s (d) 1.9×10^8 m/s
46. Which one of the following expressions determines the critical angle for quartz ($n = 1.5$) immersed in oil ($n = 1.1$)?
- (a) $\theta_c = 1.5/1.1$ (c) $\theta_c = \sin^{-1}(1.1/1.5)$ (e) $\theta_c = \tan^{-1}(1.1/1.5)$
 (b) $\theta_c = 1.5/1.1$ (d) $\theta_c = \sin(1.1/1.5)$
47. Light is incident on two slits that are separated by 0.2 mm. The figure shows the resulting interference pattern observed on a screen 1.0 m from the slits. Determine the wavelength of light used in this experiment.
- (a) 0.05 nm (c) 50 nm (e) 5000 nm
 (b) 0.50 nm (d) 500 nm



48. Two helium-filled balloons are released simultaneously at points A and B on the x axis in an earth-based reference frame. Which one of the following statements is true for an observer moving in the +x direction?

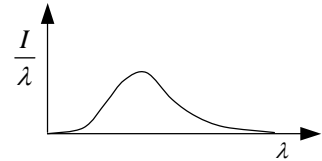


- (a) The observer always sees the balloons released simultaneously.
- (b) The observer could see either balloon released first depending on her speed and the distance between **A** and **B**.
- (c) The observer sees balloon **A** released before balloon **B**.
- (d) The observer sees balloon **B** released before balloon **A**.
- (e) The observer cannot determine whether they were released separately or simultaneously.

49. The momentum of an electron is 1.60 times larger than the value computed non-relativistically. What is the speed of the electron?

- (a) 2.94×10^8 m/s
- (b) 2.76×10^8 m/s
- (c) 2.61×10^8 m/s
- (d) 2.34×10^8 m/s
- (e) 1.83×10^8 m/s

50. The graph shows the variation in radiation intensity per unit wavelength versus wavelength for a perfect blackbody at temperature T . Complete the following statement: As the blackbody temperature is increased, the peak in intensity of this curve



- (a) will remain constant.
- (b) will be shifted to longer wavelengths and its magnitude will increase.
- (c) will be shifted to shorter wavelengths and its magnitude will increase.
- (d) will be shifted to longer wavelengths and its magnitude will decrease.
- (e) will be shifted to shorter wavelengths and its magnitude will decrease.