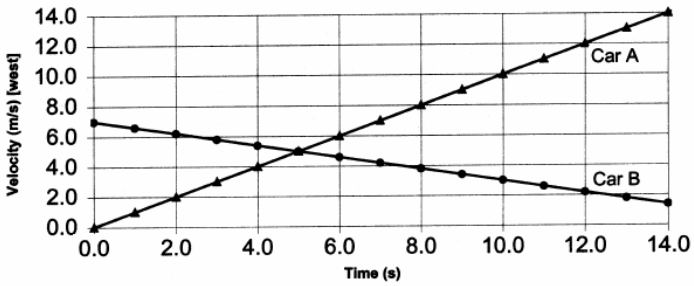
O.A.P.T. Physics Contest

Solutions 2006

Correct answers are marked with an asterisk. Solutions are intentionally terse.

1) The graph shown illustrates velocity versus time for two cars A and B constrained to move in a straight line. Both cars were at the same position at t = 0 s. Consider the following statements.



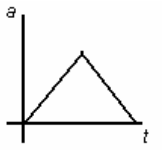
1) Car A is traveling west and Car B is traveling east.
2) Car A overtakes Car B at t = 5 s.
3) Car A overtakes Car B at t = 10 s.

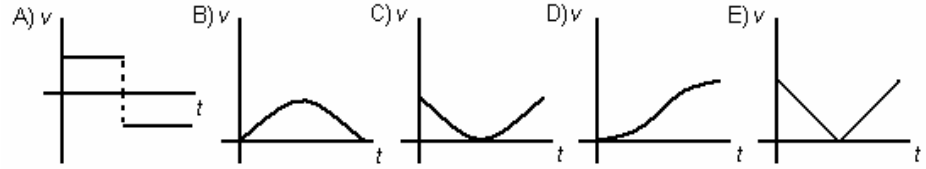
Which of the following is correct?

A) Only statement 1 is true. B) Only statement 2 is true. *C) Only statement 3 is true.
D) Only statements 1 and 2 are true. E) Only statements 1 and 3 are true.

Solution: The distance travelled by each car is equal to the area under the graph. These areas are equal at 10.0 s.

2) A changing acceleration is called "jerk". The graph shown is an acceleration versus time graph. Which of the following best represents the related velocity versus time graph? *D





Solution: The velocity is represented by the area under the acceleration vs time graph. The area is increasing at an increasing rate for the first half of the graph, and then still increasing but at a decreasing rate for the second half.

3) Two drag racers accelerate from rest down a dragstrip. The engine of each car produces a constant forward force of 1200 N on the car. Car A has a mass of 1.25×10^3 kg, while car B has a mass of 1.20×10^3 kg. When car A has gone 1.00×10^2 m, car B will be A) 2 m behind car A. B) beside car A. C) 2 m ahead of car A. *D) 4 m ahead of car A. E) 7 m ahead of car A.

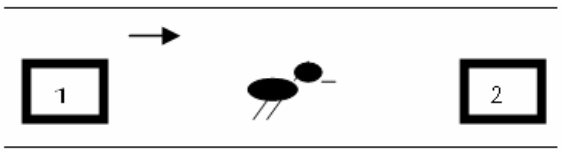
Solution:

$$a_A = \frac{1200}{1.25\times 10^3} \quad a_B = \frac{1200}{1.20\times 10^3}$$
$$= 0.960 \text{ m/s}^2 \quad = 1.00 \text{ m/s}^2$$

$$1.00\times 10^2 = \frac{1}{2}(0.960)t^2$$
$$t = 14.4 \text{ s}$$

$$d_B = \frac{1}{2}(1.00)(14.4)^2$$
$$= 104 \text{ m}$$

4) You are standing on a river bank. The river is flowing at a rate of 2.0 m/s. You see a duck in the river. You throw two pieces of bread at the duck. One piece lands in front of the duck, and the other an equal distance behind it, as shown. The duck can swim at 1.0 m/s. The duck is hungry, and wants to reach the bread in the shortest amount of time. What should the duck do?



*A) Pick one and swim for it. It takes the same time to reach both. B) Swim towards piece 1. C) Swim towards piece 2.
D) The duck should not swim at all. It cannot reach either piece since it cannot swim as fast as the river is flowing.
E) The duck should not swim at all. It should wait for piece 1 to come to it.

Solution: The duck and both pieces of bread are in the same frame of reference. Both pieces of bread are at rest with respect to the duck. It does not matter which one the duck swims for.

5) A bowling ball is tied to a rope such that the rope lifts the ball straight up at a constant velocity. The magnitude of the tension in the rope is

A) greater than the force of gravity on the ball. B) equal to the net force acting on the ball.
C) less than the force of gravity on the ball. D) equal to the mass of the ball times its acceleration.
*E) equal to the force of gravity on the ball.

Solution: Since the ball is moving upwards at a constant velocity, the net force acting on it is zero. The only forces are gravity and the force of the rope. These must be equal and opposite.

6) A shopper pushes a shopping cart down the aisle of a store with a constant force of 75 N [forward]. The shopping cart exerts a force of 75 N [backward] on the shopper

A) only if the velocity of the cart is constant. B) only if there is no friction between the cart and the floor.
C) only if the velocity of the cart is increasing. D) only if the acceleration of the cart is constant.
*E) under all circumstances assuming the system to be the shopper and cart.

Solution: This is an example of Newton's Third Law of Motion.

7) A 40 kg mass moves through a distance of 10 m on a level, frictionless surface. What is the minimum work done on the mass over this distance? *A) 0 J B)1.5×10^2 J C) 4.0×10^2 J D) 6.0×10^2 J E) There is not enough information.

Solution: If no force is applied to the mass, no work is done.

8) A railroad car is carrying sand and is rolling without friction on the railroad tracks. There is a small hole at the bottom of the car and the sand is pouring out. As the sand pours out, the speed and kinetic energy of the car will respectively

A) decrease, decrease. B) increase, decrease. *C) remain constant, decrease.
D) increase, remain constant. E) increase, increase.

Solution: Since no external force is acting on the car, its speed will not change. Since it is losing mass, its kinetic energy will decrease.

9) Denis is riding his bicycle at 12.0 km/h when he applies the brakes, locking the wheels and sliding to a stop. Denis has a mass of 15.0 kg, while the bicycle has a mass of 10.0 kg. Assuming any energy conversion is into heat, calculate the amount of heat generated by the friction between the tires and the road while coming to a stop.

A) 195 J *B) 139 J C) 108 J D) 95.0 J E) 50.0 J

Solution: $12.0 \text{ km/h} = 3.33 \text{ m/s}$

$$\begin{aligned} E_{heat} &= E_K \\ &= \frac{1}{2}(25)(3.33)^2 \\ &= 139 \text{ J} \end{aligned}$$

10) A puck starts at rest at the top of a straight, frictionless inclined plane, and slides to the bottom. When it is halfway down the ramp, the puck has
A) half of the kinetic energy it had at the top. *B) half of the potential energy it had at the top.
C) half of the speed it had at the bottom. D) taken half of the total time it would spend sliding down the ramp.
E) half the total energy it had at the top.

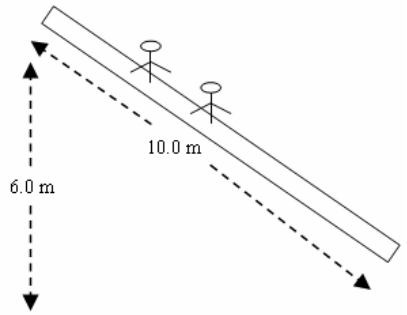
Solution: Halfway down the ramp half of the original potential energy has been converted into kinetic energy.

11) Part of the chemical energy in food consumed is converted to the kinetic energy of a runner starting from rest and reaching a speed of 2.0 m/s. The runner then increases his speed from 2.0 m/s to 4.0 m/s. The ratio of the energy required to accelerate from 2.0 m/s to 4.0 m/s, compared to the energy required to accelerate from rest to 2.0 m/s is A) 1:2. B) 1:1. C) 2:1. *D) 3:1. E) 4:1.

Solution: $E_{K0} = 0$ J The ratio is 6:2 or 3:1.

$$E_{K2} = \frac{1}{2}m(2)^2$$
$$= 2m \text{ J}$$

$$E_{K4} = \frac{1}{2}m(4)^2$$
$$= 8m \text{ J}$$



12) An escalator has 2400 W of power available to move passengers from the first floor of a mall to the second, 6.0 m vertically. If the average mass of the passengers is 65 kg, what is the maximum number of passengers that can be carried to the second floor in 1.0 minute? A) 4 B) 5 C) 22 D) 28 *E) 37

Solution: $Pt = nmgh$
$$2400(60) = n(65)(9.8)(6)$$
$$n = 37$$

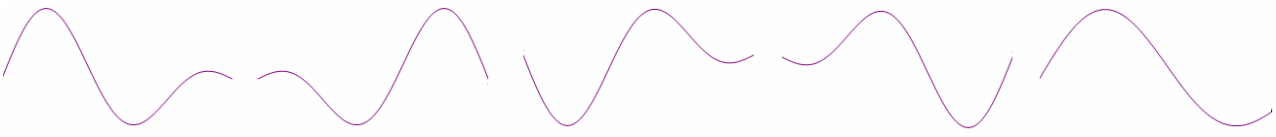
13) The distance from a compression to a rarefaction in a wave in a spring is 35.0 cm. If the frequency of the wave is 4.00 Hz, how fast is the wave travelling?

A) 280 m/s *B) 2.80 m/s C) 1.40 m/s D) 2.80 cm/s E) 1.40 cm/s

Solution: $\lambda = 0.700$ m
$$v = (4.00)(0.700)$$
$$= 2.80 \text{ m/s}$$

14) Two waves are generated in a spring, one from each end, moving towards each other, as shown. Which of the following best represents the shape of the spring when the two exactly overlap?

*A) B) C) D) E)

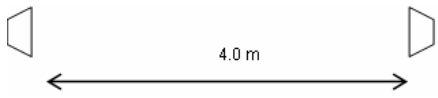


Solution: Use the Principle of Superposition at several points to determine that the answer is A.

15) A pipe organ has a frequency range of 20 Hz to 20 kHz. The longest pipe has a length of *x*, while the shortest pipe has a length of *y*. If the speed of sound is 340 m/s, what is the value of the ratio x:y?
A) 1.0×10^{-3} B) 1.7×10^{-2} C) 8.6 D) 17 *E) 1.0×10^{3}

Solution: The wavelength of the sound and the pipe length are in the same ratio, and equal to the reciprocal of the ratio of the frequencies. *y*:*x* = 20:20 000. Therefore *x*:*y* = 1000:1

16) Two speakers are situated 4.0 m apart , emitting pure sounds of 850 Hz frequency towards each other. Along the line between the sources, how far apart are the minima caused by superposition of the sound waves? The speed of sound is 340 m/s. A) 80 cm B) 40 cm *C) 20 cm D) 10 cm E) 2.5 cm



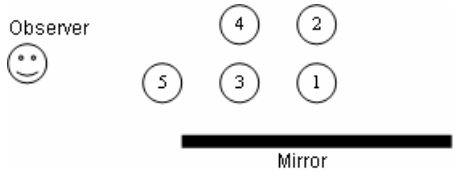
Solution: $\lambda = \dfrac{340}{850}$ Minima occur at half wavelength intervals.

$= 0.40$ m

17) As an observer walks down a street past a large, rectangular building, she hears two people talking around the corner. The reason is that
*A) sound waves diffract around obstacles. B) the sound waves reflect from the corner of the building.
C) the sound produces standing waves between the talkers and the building.
D) the temperature is hot enough that the air refracts the sound waves.
E) the temperature is cold enough that the air refracts the sound waves.

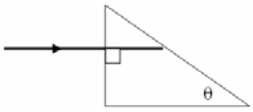
Solution: In order to "bend" around the corner of the building, the sound waves must diffract.

18) Five spheres are lined up in front of a plane mirror as shown. The observer will be able to see the reflection of:
*A) # 1 only B) #5 only C) #1 and #3 only
D) # 1,#2, #3 and #4 only E) all of the spheres



Solution: Use the first law of reflection. Only sphere #1 is in a position such that light leaving it can reflect from the mirror to the observer.

19) A ray of light is normally incident on one face of a glass prism(*n* = 1.52) as shown. The prism is immersed in oil (*n* = 1.21). Find the maximum possible value of θ such that the ray is totally reflected internally in the prism.
A) 23.6° *B) 37.2° C) 52.8° D) 66.4° E) Total internal reflection is not possible for any θ.



Solution: Total internal reflection occurs when the angle of refraction reaches 90º. Use Snell's Law.

$\dfrac{\sin \angle i}{\sin 90°} = \dfrac{1.21}{1.52}$ Use plane geometry to show that θ is the supplement of the angle of incidence, or 37.2º.

$\angle i = 52.8°$

20) A scuba diver in an empty swimming pool uses a magnifier (*n* = 1.25) to enlarge the print on a plastic instruction sheet. If the pool is filled with water (*n* = 1.33), what happens to the magnification of the print?
A) It increases and is greater than one. B) It stays the same. C) It decreases, but is still greater than one.
*D) It decreases and is less than one E) It is zero.

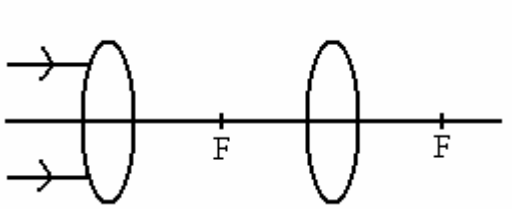
Solution: Since the water has a greater index of refraction than the lens, the magnifier now acts like a diverging lens, resulting in an image that is smaller than the object.

21) The overall angular magnification of an astronomical telescope is 25X. The objective lens has a focal length of 80 cm. What is the focal length of the eyepiece?
A) 2.0 cm B) 2.4 cm *C) 3.2 cm D) 4.8 cm E) 6.4 cm

Solution: $25 = \dfrac{80}{f_e}$

$f_e = 3.2$ cm

22) Two identical lenses are placed such that their focal points coincide as shown. Two parallel rays of light are sent into the first lens. After passing through the second lens, the two rays will



*A) be parallel. B) diverge.
C) converge and meet between the lens and the focal point.
D) converge and meet at the focal point.
E) converge and meet to the right of the focal point.

Solution: Use the rules for ray tracing to show that the emergent rays must be parallel.

23) A rechargeable cell produces a voltage of 1.60 V, and is connected to a resistor of 2.00 Ω. The current flows for 1.00 h. The energy dissipated in the resistor in this time is
A) 0.781 J. B) 1.28 J. C) 76.8 J. *D) 4.61×10^3 J. E) 9.22×10^3 J.

Solution: $E = \dfrac{V^2 t}{R}$

$= \dfrac{1.60^2 \times 3600}{2.00}$

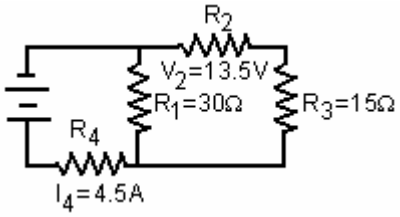
$= 4608$ J

24) A conductor is in the shape of a cylinder 20 cm long. It is connected to a power supply of constant voltage, and draws a current of 20 mA. The cylinder is stretched uniformly to a length of 1.0 m. If it is connected to the same power supply, what current will it draw?

*A) 0.80 mA B) 4.0 mA C) 20 mA D) 1.0×10^2 mA E) 5.0×10^2 mA

Solution: The length increases by a factor of 5. The cross-sectional area decreases by a factor of 5, in order to maintain a constant volume. The current decreases by a factor of 25.

25) Consider the circuit shown. The currents through R_1 and R_2 are, respectively



A) 4.5 A, 1.8 A. B) 2.7 A, 1.8 A. *C) 1.8 A, 2.7 A. D) 3.0 A, 2.0 A. E) 5.0 A, 2.0 A.

Solution: $I_1R_1 = 13.5 + I_2R_3$

$I_1 + I_2 = 4.5$

Putting in the values:

$30I_1 = 13.5 + 15\ I_2$.

Solve these as simultaneous equations to obtain answer C.

26) A 60 W light bulb is on for 2.0 h. If it were on for 4.0 h, then it would draw a power of
A) 15 W. B) 30 W. *C) 60 W. D) 120 W. E) 240 W.

Solution: The power is not dependent on the time.

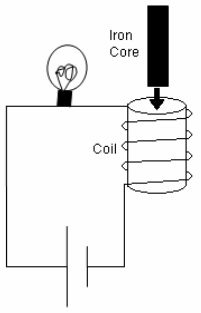
27) A thick wire is placed in a north-south direction. The wire is connected to a power supply such that a direct current of 100 A flows from north to south in the wire using the electron flow current convention. A magnetic compass is placed above the wire. Under these conditions, the compass will turn to point

A) north. B) south. *C) east. D) west. E) in no particular direction.

Solution: Use the left hand rule for the electron flow convention. The flux lines above the wire point east.

28) Wire is wrapped around a hollow cardboard tube to make a coil. The coil is connected to a cell in series with a light bulb and the brightness of the light bulb is noted. An iron core is now placed into the coil. When the core is in place, the light bulb will

A) be dimmer. *B) be the same brightness. C) be brighter.
D) alternate in brightness. E) go out.



Solution: The core does not affect the resistance of the coil, which is the only factor that determines the current.

29) Hurricane Katrina caused devastation in several countries. Surface temperatures in the ocean must be above 26°C in order for a tropical storm to develop into a hurricane. As global climate change causes oceans to become warmer, what effect will this have on hurricanes?

A) Warmer temperatures will increase the number of hurricanes that form each year.
B) Warmer temperatures will increase the strength of each hurricane.
*C) .Warmer temperatures will increase the number and strength of hurricanes that form each year.
D) Warmer temperatures will make the eye of each hurricane smaller.
E) Warmer temperatures have no effect on the number or strength of hurricanes.

Solution: Warmer temperatures result in more areas of water that are above the temperature required to develop hurricanes. More hurricanes will occur. Since they have more energy to draw on, they will also increase in strength.

30) The Nobel Prize in physics for 2005 was split among three researchers. They shared a common link. All three

A) worked at Harvard University. *B) worked in the field of optics.
C) were German nationals. D) graduated from the University of Colorado.
E) developed techniques in spectroscopy.

Solution: Use a search engine to find information on Nobel prizes and recipients.