O.A.P.T. Physics Contest

The Ontario Association of Physics Teachers is affiliated with The American Association of Physics Teachers

Tuesday, May 3, 2005 **Time: 1.0 hour**

Solutions

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Note: These solutions are intended as an indication of a possible path to the answer, and do not include all details or calculations.

1) A student was riding home in a school bus, which was moving down the highway in a straight line at a constant speed. All measurements in this problem are relative to an origin located at the student. The student tossed a ball straight up. If the ball did not hit anything during its flight and air resistance is negligible, where did it land?

*A) at the point of launch B) behind the point of launch C) ahead of the point of launch
D) at the rear window of the bus E) it depends on the speed of the bus

Solution: Since the school bus is moving in a straight line at a constant speed, it is an inertial frame of reference. Newton's Laws are valid. A ball thrown straight up will fall back straight down, returning to the point of launch.

2) During the first 17 minutes of a 1.0 hour bus trip, the average speed of the bus was 13 m/s. What was the average speed during the remainder of the trip, if the bus had an average speed of 20 m/s for the entire trip?

A) 20 m/s *B) 23 m/s C) 25 m/s D) 27 m/s E) 33 m/s

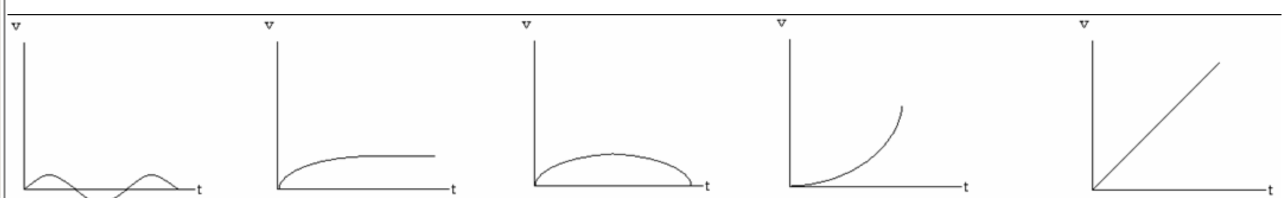
Solution: At an average speed of 20 m/s, the bus travelled a distance of 20 m/s × 3600 s = 72 000 m. During the first 17 minutes, it travelled a distance of 13 m/s × 17 × 60 s = 13 260 m. This left the bus 43 minutes to travel the remaining 58 740 m, requiring a speed of 23 m/s.

3) While solving a kinematics problem for the motion of an object, a student obtained the following result:

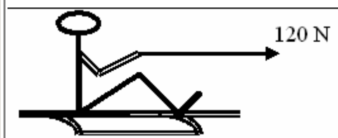
$a = k - bv$, where a is acceleration, v is speed and k and b are positive constants.

Given that at $t = 0$, $v = 0$, which of the following v versus t graphs is consistent with the equation?

A) *B) C) D) E)

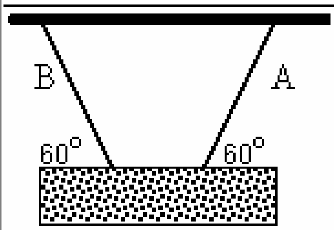


Solution: At *t* = 0, *a* = k. As *v* increases, *a* decreases, getting closer to 0. Since *a* represents the slope of the *v* vs *t* graph, the best graph consistent with this behaviour is B. C is eliminated, since it shows *a* as having a negative value when *v* decreases, which is not correct.



4) A child with mass 30 kg was sitting on a sled with mass 10 kg. The friction between the sled and the snow was negligible. If a force of 120 N was applied to the child, as shown, what was the minimum coefficient of static friction required between the child and the sled to keep the child from slipping off? A) 0.03 *B) 0.10 C) 0.20 D) 0.31 E) 0.41

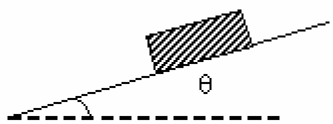
Solution: The child plus sled combination has a total mass of 40 kg. Hence, it will accelerate at 3 m/s^2 with an external force of 120 N. In order to accelerate the sled at 3 m/s^2, the sled must experience a force of 30 N, which is applied by the friction between the child and the sled. Since the normal force F_N = mg = 300 N, the coefficient of friction must be 0.10.



5) A 6.0 kg object was suspended from ropes A and B, both of which are at 60º angles to the horizontal, as shown. What was the tension in rope A?

A) 29 N *B)34 N C) 42 N D) 59 N E) 100 N

Solution: The vertical components of the tensions in ropes A and B must support the object. Let the tension in each rope be F. Therefore, 2Fsin 60º = 6.0g. Solve for F.



6) A block was at rest on an inclined plane. The coefficient of static friction between the block and the plane was 0.12. The angle θ was increased from zero. At what value of θ did the block begin to slide down the plane?

A) 5.7º *B) 6.8º C) 6.9º D) 83º E) The value of θ depends on the mass of the block.

Solution: The friction between the block and the plane is given by μF_N = μmgcos θ. The component of the weight of the block acting down the hill is mgsin θ. Equate these expressions, and solve for θ.

7) A forensic physicist fired a bullet of mass 30.0 g and a muzzle velocity of 300 m/s from a gun into a gel which simulates a human body. The bullet penetrated the gel to a depth of 10.0 cm before stopping. What was the average retarding force that the gel exerted on the bullet?

A) 1.35×10^2 N B) 4.50×10^2 N *C) 1.35×10^4 N D) 1.35×10^5 N E) 1.35×10^7 N

Solution: The kinetic energy of the bullet is dissipated as heat by doing work on the gel. Set the kinetic energy equal to the work, and solve for F.

8) A mountain climber threw a stone vertically downward from the edge of a cliff with an initial speed of 5.0 m/s. Air resistance may be ignored. The stone reached a speed of 20 m/s just before hitting the ground. If he had thrown the stone horizontally outward from the cliff with a speed of 5.0 m/s, what vertical speed would the stone have reached just before hitting the ground?

A) 5.0 m/s B) 15 m/s *C) 20 m/s D) 21 m/s E) The height of the cliff is needed to answer this question.

Solution: When the stone is thrown downwards, the kinetic energy just before it hits equals the sum of the kinetic energy with which it is thrown and the gravitational potential energy of the cliff. Use this to find the height of the cliff. When it is thrown sideways, the horizontal motion does not affect the vertical motion, and may be ignored. In this case, all of the potential energy becomes kinetic energy just before it hits. Use this to find the speed just before it hits the ground. Note: A flaw in the question paper resulted in the correct answer of 19 m/s not being one of the selections. However, answer (C) is till the best answer, which is what is asked for.

9) Equal forces were applied to three objects, P, Q, and R, initially at rest on a frictionless surface. If mP < mQ < mR,

which of the objects would have the greatest kinetic energy after traveling the same distance d?

A) P B) Q C) R *D) All will have the same kinetic energy. E) There is not enough information given.

Solution: The work done on each object is Fd. Therefore, each will receive the same kinetic energy.

10) A 40.0 kg sand bag, resting on the ground, was pulled upwards, with an acceleration of 4.00 m/s^2, by a force F. How much work was done by force F when the bag reached a height 5.00 m above the ground?

A) 320 J B) 800 J C) 1960 J D) 2000J *E) 2760 J

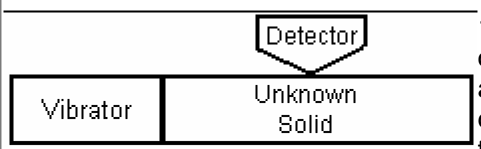
Solution: The force F applied to the bag must lift it, and accelerate it at 4.00 m/s^2. Hence, F = mg + ma. Use this to calculate F. Then, calculate the work done in 5.00 m.

11) A conveyor belt 20.0 m long and at an angle of 30º to the horizontal was designed to carry 40.0 kg sacks of chicken feed, at a constant speed of 1.00 m/s, up to a barn loft. One sack is on the conveyor at a time. How much useful power must the motor driving the conveyor belt develop? *A) 196 W B) 392 W C) 3920 W D)7840 W E) 7860 W

Solution: The belt requires 20 s to move a bag of feed to the loft. The vertical height of the loft is h = 20.0sin 30º = 10.0 m. Calculate the power using P = mgh/t.

12) A car moving at 40 km/h skidded 5.0 m to a stop after the driver locked the brakes. How far would the car skid with locked brakes if initially traveling at 120 km/h? A) 10 m B) 15 m C) 20 m D) 30 m *E) 45 m

Solution: At 120 km/h, the car will have 3^2 = 9 times the kinetic energy that it had at 40 km/h. Since the force doing the work to stop the car is the same, it will take 9 times the stopping distance.

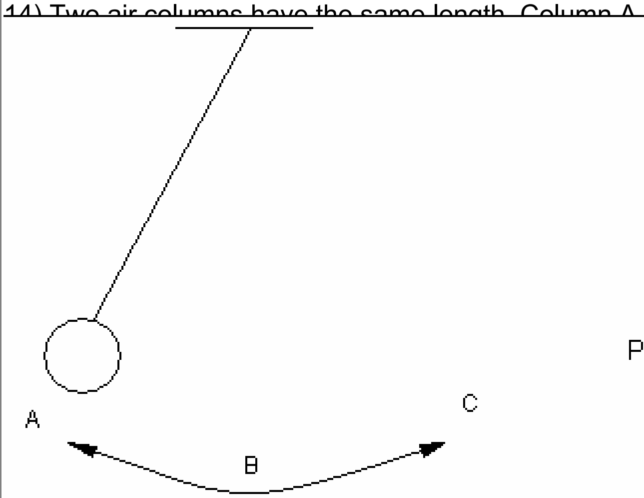


13) A vibrator was placed in contact with a solid. It was driven at a frequency of 1.24 kHz, and created standing waves in the solid. A detector was slid along the solid. Successive signal maxima occurred at the following distances from the end: 14.3 cm, 42.9 cm, 71.5 cm and 100.1 cm. What was the speed of sound in this solid?

A: 177 m/s B: 355 m/s C: 532 m/s *D: 709 m/s E: 1240 m/s

Solution: The difference between successive signal maxima is 28.6 cm, which is half a wavelength. Use this to find the wavelength, and then the Universal Wave Equation to find the speed.

14) Two air columns have the same length. Column A is closed at one end and column B is open at both ends. A d lowest resonant frequency. The ratio of the third lowest ant frequency of column B is:



Solution: The third lowest resonance in a closed column forms 5/4 of a wavelength. The third lowest resonance in an open column forms 3/2 of a wavelength. Therefore, the frequencies are in the ratio 5/4 to 3/2, or 5:6.

15) A student attached a buzzer to the bob of a pendulum. The buzzer produced a note of constant frequency 1000 Hz. The pendulum was set in motion, swinging from A toward B,

as shown. When will an observer at point P hear the highest frequency?

A) When the bob is at point A. B) When the bob is at point C.
*C) When the bob is at point B, moving towards the observer.
D) When the bob is at point B, moving away from the observer.
E) The observer will always hear a frequency of 1000 Hz.

Solution: The highest frequency heard by the observer occurs when the bob is moving towards the observer at the highest speed, which is at point B.

16) Pilots often use headsets with active noise reduction (ANR) to reduce ambient noise in the cockpit environment by canceling the noise electronically. These headsets principally make use of

A) resonance B) standing waves C) phase shift *D) the principle of superposition E) reflection

Solution: The ANR electronics split the noise signal, invert one of the parts, and add them back together, cancelling the noise using the principle of superposition. Although this can be a considered as a phase shift, it is not the phase shift itself that results in the cancellation of the noise.

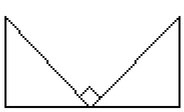
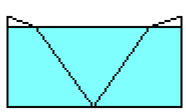
17) The walls and ceiling of a concert hall are usually constructed with irregular surfaces, and parallel or perpendicular surfaces are avoided. This is done to

*A) avoid standing wave patterns from forming.
B) favour the formation of standing wave patterns.
C) increase the time taken for a sound made in the hall to die out.
D) increase the speed of sound in the hall.
E) create a visually pleasing environment for the audience.

Solution: Standing wave formation requires waves moving in opposite directions at the same time. Irregular surfaces prevent this from happening.

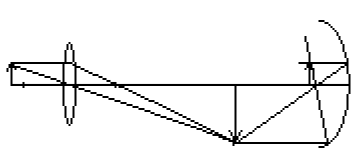
18) A scuba diver was lying "attached to" the bottom of an empty indoor swimming pool, looking up. The rays coming from the opposite edges of the pool made an angle of 90º at his eyes. If the pool is filled with water (n = 1.33) to a level of a few centimeters below the edges, submerging the diver, what angle will the edges form, as seen by the diver?
A) greater than 90º B) exactly 90º *C) less than 90º D) 0º E) The diver will not be able to see the edges.

Solution: Sketch two diagrams.

19) An object was placed 25 cm in front of a converging lens with a focal length of 20 cm. A concave mirror with a focal length of 15 cm was placed 120 cm behind the lens. Which of these describes the final image?

*A) real, upright B) virtual, upright C) real, inverted D) virtual, inverted E) inverted, enlarged



Solution: Sketch a ray diagram.

20) Without her contact lenses, a student can focus an object located 0.80 m to infinity from her eyes. The power of a lens, measured in diopters, is the reciprocal of the focal length, measured in meters. Assuming that the image distance in the eye is 0.02 m, what lens power does she require for reading a text located 0.25 m from her eyes?

A) 1.25 diopters B) 5.25 diopters C) 5.25 diopters *D) 2.75 diopters E) –2.75 diopters

Solution: The student can focus up to 0.80 m, and still form an image at a distance of 0.02 m. Use the lens equation to determine the focal length of the lens in her eye under these conditions, and hence the power. Then, use the same equation to determine the power required to form an image of an object 0.25 m away from the eye. Use the two powers to determine how much power must be added to the lens in her eye.

21) A student noticed a rainbow appearing in the sky. As he walked towards it, what happened to the apparent height of the rainbow above the ground?

A) It increased very slowly. B) It increased very quickly. C) It decreased very slowly.
D) It decreased very quickly. *E) It remained the same.

Solution: The perception of a rainbow depends on the proper angles between the sun, the raindrops, and the eye. Hence, the rainbow will appear at the same place relative to the student as long as the time is short enough that the sun does not change it's position appreciably, as in this question.

22) Prisms are often used in binoculars made with two converging lenses. They are used

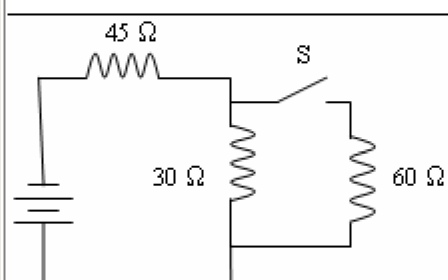
A) to lengthen the optical path. B) to ensure that the final image seen is erect.
C) because they absorb less light than mirrors. D) to allow shorter "tubes" to be used.
*E) for all these reasons.

Solution: To see how the prisms in binoculars work, consult any elementary physics text.

23) It requires 334 000 J/kg to melt ice at 0ºC to water at 0ºC. A windshield defroster on a car consisted of 20 wires connected in parallel, each of resistance 2.00 Ω, connected to a heavy duty, 12.0 V electrical system. How long did it take to melt 1.00 kg of ice?

A) 58.0 s B) 69.4 s *C) 232 s D) 8.33×10^{3} s E) 9.25×10^{4} s

Solution: The parallel resistance of twenty 2.00 Ω resistors can be calculated as 0.100 Ω, drawing a current of 120 A, for a power rating of 1440 W. Divide this into the heat of fusion to determine the time required to melt 1.00 kg of ice.



24) Three resistors, and a switch were connected as shown. When the switch was closed, what happened to the potential difference across the 30 Ω resistor?

A) It stayed the same. *B) It decreased. C) It increased.
D) It became twice the potential difference across 60 Ω resistor.
E) It became equal to the potential difference across the 45 Ω resistor.

Solution: When the switch was closed, the effective resistance of the second part of the circuit decreased, increasing the current drawn from the power supply. The voltage drop across the 45 Ω resistor increased, decreasing the voltage drop across the 30 Ω - 60 Ω pair.

25) The magnetic field around a current-carrying, circular loop is most like that of

A) a current-carrying rectangular loop B) a long current-carrying straight wire C) the Earth
*D) a very short bar magnet E) two parallel wires with currents in opposite directions

Solution: A single loop is like a very short helix. Since the field around a helix resembles that of a bar magnet, the field around a short helix resembles that of a very short bar magnet.

26) The data "stripe" on the back of a credit card can be erased by

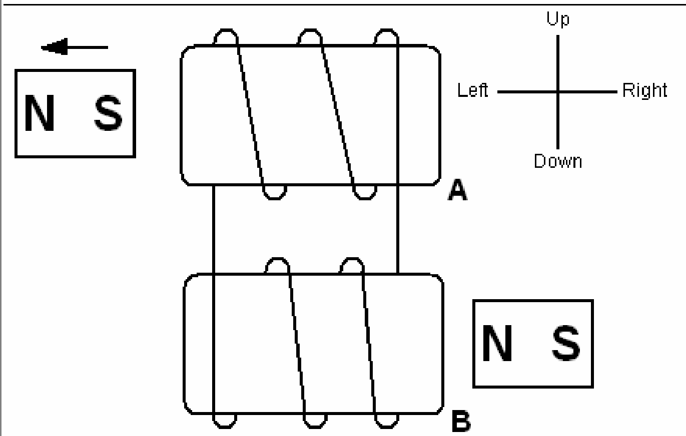
A) touching it to the negative terminal of a 12 V automobile battery.
B) touching it to the positive terminal of a 12 V automobile battery.
C) connecting it between the terminals of a 12 V automobile battery using wires and alligator clips.
*D) rubbing it with a strong magnet. E) exposing it to an ultraviolet lamp powered by alternating current.

Solution: The data stripe on a credit card is magnetically encoded. Hence, a magnetic field will erase it.

27) A student decided to make some fashionable "web" lighting using several strings of old holiday lights. Each of the lights had a resistance of 10 Ω. She cut the old strings into strings of 20 lamps each. Then, she connected 20 of these strings in parallel. The total effective resistance of the completed web was

A) 0.5 Ω. B) 1 Ω. *C) 10 Ω. D) 200 Ω. E) 40 000 Ω.

Solution: Connecting 20 lights in series increases the resistance by a factor of 20. However, connected 20 of these in parallel decreases the resistance by a factor of 20. Hence, the effective resistance of the web is 10 Ω.



28) A bar magnet was pulled away from a hollow coil A as shown. As the south pole came out of the coil, the bar magnet next to hollow coil B experienced a magnetic force
*A) to the right. B) to the left. C) upwards. D) downwards.
E) of zero.

Solution: Moving the bar magnet away from the coil induces a north pole at the left of the top coil. Use either the Left Hand or the Right Hand rule convention to determine flow around the circuit. Then, use the helix rule to determine that the pole on the right of the lower coil is a north pole, pushing the bar magnet away to the right.

29) Americans David J. Gross, H. David Politzer and Frank Wilczeck won the 2004 Nobel Prize in physics for the discovery of asymptotic freedom in the theory of

A) the electromagnetic force. B) the gravitational force.
C) the weak force. *D) the strong force.
E) all of the above.

Solution: Refer to any source on the Nobel Prize.

30) Canadian Light Source is a new $174-million research facility opened in October 2004 in Saskatoon. It uses a pencil-thin beam of photons. The beam is

*A) synchrotron radiation. B) light from an ultra-strong new generation laser.
C) given off by colliding beams of protons and antiprotons. D) radiated by off by electrons in a linear accelerator.
E) radiation given off by accelerated protons.

Solution: Refer to a scientific periodical index, or search the Internet for the keywords "Canadian Light Source".