O.A.P.T. Physics Contest

2002 Solutions

Jump to Question:

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30

Question 1

1) If an apple starts from rest and falls freely for 3.00 s then its average speed during these 3.00 s is

A) 0 m/s. B) 4.90 m/s. C) 9.80 m/s. D) 14.7 m/s. E) 19.6 m/s.

Solution

Solution for Question 1

The apple is freely falling with an acceleration of 9.80 m/s^2. After 3.00 s, the final speed will be 29.4 m/s. Since the acceleration is constant, the average speed is the initial speed of zero plus the final speed of 29.4 m/s, divided by two.

Hence the correct answer is: D) 14.7 m/s.

Question 2

2) An astronaut tossed a ball vertically upwards on the moon. It reached a height of 85 m before landing back in her hand 20 s after leaving it. You may ignore air resistance in this question. If the same ball were thrown upward on Earth with the same initial speed as on the moon, it would be in flight for

A) 20 s. B) 17 s. C) 10 s. D) 3.5 s. E) 1.7 s.

Solution

Solution for Question 2

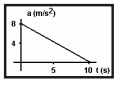
Since the total flight time on the moon was 20 s, the ball took t = 10 s to slow to a final speed v = 0 m/s over 85 m. We may use the equation d = ½(u+v)t to calculate the initial speed u = 17 m/s. On Earth, g = 9.80 m/s^2, so we may calculate the time required to stop from v = u + at. Doubling this gives the total flight time.

Hence the correct answer is: D) 3.5 s.

Question 3

3) A graph of acceleration in m/s^2 versus time in s is shown. The change in velocity of this object from t = 0 s to t = 10 s is closest to

A) 40 m/s. B) -40 m/s. C) 80 m/s. D) –80 m/s. E) 0 m/s.



Solution

Solution for Question 3

The average acceleration for this object, from the graph, is about 4.0 m/s^2. The equation $\Delta v = at$ allows us to calculate the change in velocity.

Hence the correct answer is: A) 40 m/s.

Question 4

4) A hockey rink was made from the new plastic "Sliplon", which is completely frictionless. If a player is not permitted to throw anything away from him, which of the following actions would be possible on this new hockey rink? You may assume that the mass of air molecules is negligible.

A) a player at rest could accelerate B) a player moving could come to a stop
C) a moving player could turn to his right
D) all of these E) none of these

Solution

Solution for Question 4

Since the playing surface is frictionless, and since the player is not permitted to throw anything away from him, there is no way for the player to apply an external force on himself. Hence, his state of motion cannot be changed. The correct answer is: (E).

Question 5

5) If you push on a cart on a railroad with a force of 500 N and it doesn't move, you can conclude that

A) there is a force of 500 N in the opposite direction acting on the cart.
B) Newton's second law is not valid in such a frame of reference.
C) the force is canceled by the reaction force.
D) the cart has too much mass to accelerate.
E) the normal force is greater than 500 N.

Solution

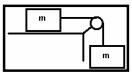
Solution for Question 5

If the cart does not move, Newton's Second Law says that the net force acting on it is zero. Therefore, there must be an opposing force of 500 N cancelling the applied force of 500 N, leading to answer (A).

Question 6

6) A light string passing over a small pulley, as shown, attaches two identical masses. The table and the pulley are frictionless. The system is moving with an acceleration

A) of zero. B) of exactly 2g. C) greater than g but less than 2g.
D) equal to g. E) less than g.



Solution

Solution for Question 6

The net force accelerating the system is provided by the hanging mass, and is equal to mg. The total mass being accelerated is 2m. Hence, Newton's Second Law predicts that the acceleration will be mg/2m = g/2. The best answer is (E), less than g.

Question 7

7) A box at rest at the top of a frictionless hill is allowed to slide down the hill. At the bottom of the hill the speed of the box is 8 km/h. Next, the box is allowed to slide down the hill with an initial velocity of 6 km/h. How fast is the box going when it gets to the bottom of the hill?

A) 6 km/h B) 8 km/h C) 10 km/h D) 12 km/h E) 14 km/h

Solution

Solution for Question 7

If the box begins from rest, the energy relation between the top of the hill and the bottom of the hill is: $mgh = \frac{1}{2}mv^2$. If the speed at the bottom is 8 km/h, then $gh = 32$. If the box begins with a speed of 6 km/h, then the energy relation is:

$mgh + \frac{1}{2}mv_o^2 = \frac{1}{2}mv^2$

Hence, $32 + 18 = \frac{1}{2}v^2$, and v = 10 km/h, or answer (C).

Question 8

8) A girl with a heavy backpack wants to climb to the top of a hill. The path straight up the hill is 100 m long. Rather than going straight up she chooses a zigzag path 200 m long. The work she does on the backpack is ___ the work she does on the backpack going up in a straight line.

A) ¼ of B) ⅓ of C) ½ of D) equal to E) twice

Solution

Solution for Question 8

The work done on the backpack depends only on the difference in height between the bottom of the hill and the top of the hill, and not on the path taken to get there. Hence, the correct answer is (D).

Question 9

9) A girl was swinging on a swing at the park. She was moving with constant amplitude and in regular periodic motion. She reached a maximum vertical height 1.0 m above the lowest point of the swing. How fast was she moving when she was 0.60 m above the lowest point? You may assume no friction or air resistance.

A) 4.4 m/s B) 3.9 m/s C) 3.4 m/s D) 2.8 m/s E) 2.0 m/s

Solution

Solution for Question 9

The energy relation for this question is:

$mgh_T = mgh + \frac{1}{2}mv^2$

$g(1) = g(0.6) + \frac{1}{2}v^2$

$v = 2.8$ m/s

which is answer (D).

Question 10

10) How long will it take a motor with an output power of 4000 W to lift a 250 kg container vertically upwards 25 m?

A) 0.64 s B) 1.6 s C) 15 s D) 160 s E) the motor cannot lift the container

Solution

Solution for Question 10

The amount of work that needs to be done is given by

$mgh = 250 \times 9.8 \times 25 = 61\ 250$ J.

The power available is 4 000 W. Therefore, the time required is

$t = W/P$

$= 61\ 250/4000$

$= 15$ s

which is answer (C).

Question 11

11) A bullet of mass m=8.0 g and speed 700 m/s was fired into a block of wood. Assuming a constant frictional force brought the bullet to rest 5.0 cm inside the block without deforming the bullet, what was the average acceleration of the bullet while inside the block?

A) -2.0×10^4 m/s^2 B) -8.4×10^5 m/s^2 C) -4.9×10^6 m/s^2
D) -1.0×10^7 m/s^2 E) -5.4×10^7 m/s^2

Solution

Solution for Question 11

Since you know that u = 700 m/s, v = 0 m/s and d = 0.05 m, an appropriate formula from kinematics is:

$v^2 = u^2 + 2ad$.

Substituting and solving yields the correct answer $a = -4.9 \times 10^6$ m/s^2, which is (C).

Question 12

12) Two pucks of masses $m_1 = 3M$ and $m_2 = M$ are moving in the same direction on a frictionless surface such that they have the same kinetic energy. After 2 s the same force F is applied to each puck in the opposite direction to its motion. The ratio of the stopping distances $d_1 : d_2$ is

A) 9:1. B) 3:1. C) 2:1. D) $\sqrt{3}$:1. E) 1:1.

Solution

Solution for Question 12

The stopping distance for each puck is related to its kinetic energy as follows:

E_K = Fd. Since both pucks have the same kinetic energy, and the same force is applied to each puck, the two stopping distances must be the same, which is answer (E).

Question 13

13) Fritz plucked the low "E" string on his guitar, and let it sound. A few seconds later he noticed that the high "E" string, which is two octaves above the low "E" string, was also vibrating. Each octave increase doubles the frequency. He concluded that the high "E" string was resonating with the ___ harmonic of the low "E" string.

A) first B) second C) third D) fourth E) eighth

Solution

Solution for Question 13

Let the frequency of the low "E" string be f. Since the high "E" string is two octaves above the low "E" string, its frequency is 4f. This is equal to the frequency of the fourth harmonic of the low "E", leading to answer (D).

Question 14

14) While watching the waves on a rough lake, Andree noticed that a large wave would "rise" for a few seconds, and then diminish. This was most likely caused by

A) constructive interference. B) destructive interference.
C) standing waves in the water.
D) the Doppler effect. E) resonance.

Solution

Solution for Question 14

The large wave is the result of superposition of two or more smaller waves interfering constructively, which is answer (A).

Question 15

15) The speed of sound in air at 0°C is 332 m/s, and increases by 0.60 m/s for every degree Celsius that the temperature rises. A piano tuner strikes a key that produces a 440 Hz "A" note in a room with a temperature of 20°C. A beat frequency of 26 Hz results when a tuning fork and the key are struck simultaneously. A possible wavelength of the note produced by the tuning fork is

A) 69 cm. B) 71 cm. C) 77 cm. D) 80 cm. E) 83 cm.

Solution

Solution for Question 15

Since the temperature in the room is 20ºC, the speed of sound in the room is given by v = 332 + 0.6x20 or 344 m/s. Since a beat frequency of 26 Hz is heard when the key is sounded with a 440 Hz turning fork, the key must have a frequency of either 414 Hz or 466 Hz. Using the Universal Wave Equation, $\lambda = v/f$, you can calculate the corresponding wavelengths of 83 cm and 74 cm. Only the 83 cm wavelength appears in the answer list, as answer (E).

Question 16

16) Mikhail found a steel rod one meter long. He held it in the middle, and tapped it with a hammer at one end, creating longitudinal standing waves in the rod. Mikhail knew that sound waves in steel travel at about 5,000 m/s. He heard a fundamental frequency of

A) 10,000 Hz. B) 5,000 Hz. C) 2,500 Hz. D) 1,250 Hz.
E) cannot be determined from this information.

Solution

Solution for Question 16

Since Mikhail held the rod in the middle and tapped the end, he forced a node in the middle and antinodes at the ends. Therefore, the rod was half a wavelength long. The full wavelength is twice the length of the rod, or 2 m. You can use the Universal Wave Equation $f = v/\lambda$ to calculate the frequency as 5 000/2 or 2 500 Hz, which is answer (C).

Question 17

17) A student performed an experiment using an air column closed at one end. An 880 Hz turning fork was sounded near the open end while the length of the column was adjusted. Loud sounds were heard at 9.7 cm and 29.1 cm. The room temperature at the time was close to

A) 0.0°C. B) 13.3°C. C) 15.7°C. D) 18.3°C. E) 20.0°C.

Solution

Solution for Question 17

The first loud sound occurred at the first resonant length, which is ¼ λ. The second loud sound occurred at the second resonant length, which is ¾ λ. Since the antinode does not occur exactly at the open end, subtract these two to correct for the end error. This gives you ½ λ = 19.4 cm, and λ = 38.8 cm. Since the frequency is known to be 880 Hz, you can use the Universal Wave Equation $v = f\lambda$ to calculate the speed of sound in the room as 341.4 m/s. This is 9.4 m/s above the speed at 0°C, as you know from Question 15. Divide by 0.6 to obtain the temperature of

15.7 °C, which is answer (C).

Question 18

18) On a clear and sunny day you are on snow and you look at your shadow. You see that your shadow is tinted

A) no particular colour. B) red. C) yellow. D) green. E) blue.

Solution

Solution for Question 18

Your body blocks direct light from the sun. However, scattered light from the sky will illuminate your shadow. Since the scattered light is primarily blue, your shadow will appear to be blue, which is answer (E).

Question 19

19) A student uses a magnifying glass to examine the crystals in a mineral sample. The magnifying glass contains a

A) diverging mirror. B) converging lens. C) diverging lens.
D) converging mirror. E) plane mirror.

Solution

Solution for Question 19

A magnifying glass must be a lens. A diverging lens will make an object appear smaller than it is. Therefore, the correct answer is (B).

Question 20

20) Maria showed slides by projecting them on a fixed screen. Her friend complained that the image was too small. Maria enlarged the image by moving the projector away from the screen, but the image blurred. The image should then have been brought into focus by

A) moving the lens closer to the slide.
B) moving the lens away from the slide.
C) decreasing the amount of light in the room.
D) increasing the power of the projector lamp.
E) it is not possible to focus the image.

Solution

Solution for Question 20

The relation between the image distance and the object distance for the converging lens used in a slide projector is:

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$$

In this case, d_i has been increased. Since f is constant, d_o must decrease to maintain the equality. Therefore, the lens must be moved closer to the slide, which is answer (A).

Question 21

21) A neutral density filter is a filter which absorbs the same amount of each wavelength of light incident upon it. A certain neutral density filter absorbs 50% of the light incident upon it. Two layers of this filter will absorb

A) 100% of the light. B) 75% of the light. C) 67% of the light.
D) 50% of the light. E) 25% of the light.

Solution

Solution for Question 21

Since the neutral density filter in this question absorbs 50% of the light incident upon it, the first layer will transmit 50% of the original light, and the second layer will transmit half of the 50%, or 25%. Therefore, the two layers will absorb 75% of the light, which is answer (B).

Question 22

22) The same frequency of monochromatic light is incident from air upon four lenses made of different materials but otherwise identical. The lens that has the longest focal length is made of

A) quartz (n=1.46). B) lucite (n = 1.51). C) crown glass (n = 1.54).
D) flint glass (n= 1.65). E) there is not enough information.

Solution

Solution for Question 22

The lens with the longest focal length is the lens which refracts the light the least. Since quartz has the lowest index of refraction of those given, it will have the longest focal length, which is answer (A).

Question 23

23) Three students measured the resistance of a set of three resistors in a black box. Student A said that it contains one 5 Ω resistor in series with two 10 Ω resistors in parallel. Student B said that there are three 30 Ω resistors in parallel. Student C said that there are two 20 Ω resistors in parallel connected in series to a 5 Ω resistor. Which of the students could be correct?

A) A only B) B only C) all three
D) A and B only E) B and C only

Solution

Solution for Question 23

Two 10 Ω resistors in parallel are equivalent to a single 5 Ω resistor. If put in series with another 5 Ω resistor, student A predicts a total effective resistance of 10 Ω. Student B says that there are three 30 Ω resistors in parallel, giving a total effective resistance of 10 Ω. Two 20 Ω resistors in parallel give an effective resistance of 10 Ω. If connected in series with another 5 Ω resistor, the total effective resistance predicted by student C is 15 Ω. To summarize:

Student A: 10 Ω Student B: 10 Ω Student C:15 Ω.

Since student A and student B predict the same measured result, they are either both right or both wrong. If student C is correct, then A and B must be wrong. The only answer which is consistent with these requirements is (D).

Question 24

24) In the new GPS system of navigation, spherical electromagnetic signals from a constellation of 24 satellites are used to precisely locate a receiver in three dimensions. The minimum number of satellites required to produce a unique location in three dimensions is

A) one. B) two. C) three. D) four. E) five.

Solution

Solution for Question 24

A signal from one satellite will locate the receiver somewhere on the surface of a sphere. A second signal will reduce the location to somewhere on the intersection of two spheres, which is a circle. A third signal will intersect this circle in two possible points. A fourth signal will determine which point is correct. Therefore, a minimum of four signals is required to produce a unique location in three dimensions, which is answer (D).

Question 25

25) Light bulbs A and B are identical in all ways except that B's filament is thicker than A's. If connected to the same constant voltage power supply

A) both will have the same brightness.
B) A will be brighter because it has more resistance.
C) B will be brighter because it has more resistance.
D) A will be brighter because it has less resistance.
E) B will be brighter because it has less resistance.

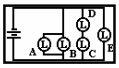
Solution

Solution for Question 25

Since the filament for bulb B is thicker, it will have less resistance. If connected to the same power supply as bulb A, it will draw a higher current and dissipate more power, making it brighter. Therefore, the correct answer is (E).

Question 26

26) The diagram at the right shows a battery and five identical light bulbs A, B, C, D and E. With the battery operating what is the correct order for the brightness of the bulbs sequenced from the brightest to the least bright?



A) A= B > E > D = C
B) A = B = E > D=C
C) A = B > D = C > E
D) E >A = B > C>D
E) E > A = B > C = D

Solution

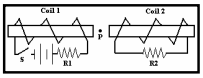
Solution for Question 26

Bulbs A, B and E are all connected in parallel to the power supply. Ergo, they will all have the same brightness. Bulbs C and D are connected in series. Therefore, they will share the voltage of the power supply, and be dimmer than the other three. The correct answer is (B).

Question 27

27) Two coils, 1 and 2, with iron cores are positioned as shown in the figure. Coil 1 is part of a circuit with a battery and a switch. Immediately after the switch S has been closed, which one of the following statements is true?

A) An induced electron current will flow from left to right in R1.
B) An induced electron current will flow from right to left in R2.
C) A magnetic field that points toward P appears inside coil 1.
D) An induced magnetic field that points toward P appears inside coil 2.
E) A current will pass through R1, but there will be no current through R2.



Solution

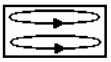
Solution for Question 27

When the switch is closed, a current will flow in coil 1, turning it into an eletromagnet. If you use Lenz's Law, you find that the north pole of the induced electromagnet in coil number one is on the left. Hence, the field at P points away from P, not towards it. The electromagnet formed in coil 1 has the same effect plunging a south pole into coil 2. A current will be induced in coil 2 to oppose this motion, resulting in a south pole at the left of coil 2, again pointing the field away from P. Hence, an induced current will flow from right to left in R_2, which is answer (B).

Question 28

28) Two conducting loops carry equal currents **I** in the same direction as shown in the figure. If the current in the upper loop suddenly drops to zero, what will happen to the current in the bottom loop according to Lenz's Law?

A) The current will decrease. B) The current will increase.
C) The current will not change. D) The current will also drop to zero.
E) The current will reverse its direction.



Solution

Solution for Question 28

According to the direction of current flow, each of the loops is creating an electromagnet with the north pole at the bottom. If the current in the top loop drops to zero, the effect is the same as pulling a north pole out of the bottom loop. Lenz's Law predicts that the current in the bottom loop will change in such a way as to oppose this motion, which requires a stronger south pole at the top of the bottom loop. This is accomplished by increasing the current in the bottom loop, which is answer (B).

Question 29

29) The 2001 Nobel Prize for physics was awarded for creating a new state of matter called a Bose-Einstein Condensate BEC with far-reaching potential for smaller and faster electronics and ultra-precise measuring instruments. In what year was the experiment that first produced BEC done?

A) 2001 B) 1999 C) 1995 D) 1924 E) 1901

Solution

Solution for Question 29

The correct answer is (C) 1995. Information on Nobel prizes can be found in various places, such as http://www.nobelprizes.com/. The OAPT contest always contains one question on the current Nobel Prize in physics.

Question 30

30) Space Station Alpha One is currently under construction in space. The astronauts aboard the station find it necessary to communicate with different ground stations as time passes. This is because Space Station Alpha One's orbit is

A) geosynchronous.
B) polar.
C) in the same direction as the rotation of the Earth but with a shorter period.
D) in the same direction as the rotation of the Earth but with a longer period.
E) in the opposite direction to the rotation of the Earth.

Solution

Solution for Question 30

Satellites are launched with the rotation of the Earth in order to gain speed advantage from the rotation of the Earth. Satellites in low orbits like the space station have short periods, usually a few hours. Therefore, the correct answer is (C). The OAPT contest always contains one question based on current events in physics.



O.A.P.T. Physics Contest

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The End

Please direct questions, concerns or errors to:

Rolly Meisel (rollym@vaxxine.com)