American Association of Physics Teachers

PHYSICSBOWL 2007

Answer Key

1. d
2. d
3. a
4. e
5. c
6. c
7. a
8. b
9. e
10. b
11. d
12. e
13. a
14. c
15. d
16. c
17. a
18. e
19. d
20. b
21. a
22. d
23. c
24. c
25. d
26. b
27. b
28. a
29. c
30. e
31. b
32. b
33. c
34. a
35. d
36. e
37. b
38. e
39. a
40. c
41. d
42. e
43. b
44. e
45. e
46. a
47. c
48. d
49. c
50. a

Solutions

1. **D…** Proper measurement technique means that one must estimate the NEXT digit past what is read. Here, we can see that the end of the object is at 10.0 cm and we estimate the hundredths place to be 0 as the object looks to line up exactly with the mark.
2. **D…** A book that is an inch thick is about 500 pages, which means 250 sheets of paper. There are about 2.5 cm in an inch. So, about 100 sheets per cm, Hence, there are 0.01 cm/sheet which is $\frac{0.01cm}{sheet}\frac{10^4\ \mu m}{1cm}=\frac{100\mu m}{sheet}$
3. **A…** From the point of view of one of the vehicles, the other looks to move at 100 km/h. Hence, it takes $150km \big/ 100\,km/h = 1.5\,h$ for the cars to meet.
4. **E…** A particle could be moving to the *right (positive velocity)*, in which case the acceleration speeds the particle up. The particle could be moving to the *left (negative velocity)*, in which case the acceleration is causing the particle to slow down. There is no information about the velocity of the particle, so no conclusion can be made.
5. **C…** Since the position moves upward and then downward, this graph is reminiscent of a particle in free fall as it is parabolic… hence, the acceleration is a negative constant.
6. **C…** There are a couple of options here…
   Method 1: Force… using constant acceleration kinematics,
   $v_f^2 = v_0^2 + 2a\Delta x \rightarrow a = \frac{v_f^2 - v_0^2}{2\Delta x} = \frac{-28^2}{2(95)} = -4.13\frac{m}{s^2}$. Hence, from Newton's Second Law, $F_{net} = ma = (500)(-4.13) = -2060\,N$
   Method 2: Energy… The force of stopping converts the kinetic energy of the car to thermal energy… hence, one can write $W_{net} = \Delta KE \Rightarrow -Fd = -\frac{1}{2}mv_o^2 \rightarrow F = \frac{mv_o^2}{2d} = 2060\,N$
7. **A…** By ignoring friction, there is no loss or gain of energy to the system as potential energy and kinetic energy are constantly transformed into each other.
8. **B…** $\frac{12\,Mm}{4Ts} = \frac{12\times10^6\,m}{4\times10^{12}\,s} = 3\times10^{-6}\frac{m}{s} = 3\,\mu m/s$
9. **E…** As the angle increases… the normal force becomes less as a smaller amount of the gravitational force is directed into the plane of the incline. Meanwhile, the static friction force has to increase as the gravitational force component down the incline becomes larger.
10. **B…** Contact forces arise from the interaction of molecules between the surfaces… these arise from the positive and negative charges… hence the forces are electromagnetic.

11. **D … Method 1: kinematics**… since the track is the same, then the acceleration is the same. Hence, using $v^2 = v_0^2 + 2a\Delta x \Rightarrow \Delta x = {-v_0^2}/{2a}$. Hence, since the speed is doubled, the distance traveled is quadrupled! The total distance is 4.0 m.
Method 2: energy… Friction is reducing the speed of the object. The change in kinetic energy is equated to the increase in the thermal energy from
$\Delta KE + \Delta E_{thermal} = 0 \Rightarrow \left(0 - \tfrac{1}{2}mv^2\right) + fd = 0 \;\Rightarrow\; d = \dfrac{\tfrac{1}{2}mv^2}{f}$. As the mass and friction are unchanged here, the distance traveled is 4 times greater when the speed is twice as great.
12. **E…** Average velocity is defined as the displacement divided by the time
13. **A…** Since the scale reads a higher number than the gravitational force on the student… this means that there is a net force UPWARD on the student meaning that the student accelerates upward.
14. **C…** With a constant force applied to the North, the path will be parabolic opening to the North. This is akin to an object moving to the right and then falling off of a table. The path would be a parabola opening downward in the direction of the gravitational force.
15. **D…** By conservation of energy, the objects have no total change in vertical position meaning that the change in the earth-object system in both cases is zero. Hence, each object returns to the launch point with the same speed that it had at launch.
16. **C…** Using the impulse-momentum theorem, the change in momentum equals the net force multiplied by the time. Since the force on each object is the same, the object in the air for a longer time experiences a larger momentum change. Since Object 2 is launched at a higher angle, it reaches a higher position above the ground and takes longer to return to the ground.
17. **A…** The acceleration is found from taking the slope of the line tangent to each point on the velocity-time graph. Zero acceleration occurs when the line tangent is horizontal. This occurs at times t=2 and t=4 seconds.
18. **E…** There is a net force on the mass on a pendulum since its speed and direction of motion keep changing. Answer B is not correct because the stone is in free fall. Answer C is not correct as the astronaut is accelerating toward the Earth (circular motion). Answer E is not correct as the person would increase speed as they ride down the hill. Terminal velocity (when the object achieves its maximum speed) means that there is no acceleration.
19. **D…** We use Newton's Second Law in the form

$$F_{net} = ma = m\,{v^2}/{r} = (1.0\,kg)\left(\frac{\left(2.0\,{m}/{s}\right)^2}{0.5\,m}\right) = 8.0\,N$$

20. **B…** The free body diagram of the block-wedge system has only 3 vertical forces: the gravitational forces on the block and on the wedge and an upward normal force on the wedge. Hence, the center-of-mass does not move horizontally (no net horizontal force). As for the vertical component… since the wedge does not change its vertical position while the block moves down, the only answer that can possibly be correct is b). For this scenario, the block will accelerate down the wedge.
21. **A…** Since the box accelerates to the right, there is a net force in that direction from T. As M is ½ the size of T, the other force acting to the left must therefore be less than M. Hence $f < M < T$.
22. **D…** The object will accelerate toward the pivot point when it swings through the bottom of the arc. Using Newton's Second Law, we have $F_{net} = ma \Rightarrow T - mg = m\dfrac{v^2}{L}$. The speed at the bottom of the arc is found through energy conservation yielding

$\Delta KE + \Delta PE = 0 \Rightarrow \left(\tfrac{1}{2}mv^2 - 0\right) + mg(-L) = 0 \Rightarrow v^2 = 2gL$. Substituting back into our force expression, we find $T - mg = m\frac{2gL}{L} \Rightarrow T = 3mg$

23. **C…** The period of the mass-spring system depends on the spring constant and the mass… not the amplitude.
24. **C…** Since the standing wave mode has a displacement antinode at the opening, there is a displacement node at the water-air interface. By increasing the height of the air column, to go from one harmonic to the next, an additional length equal to ½ wavelength is required. Hence, $\tfrac{1}{2}\lambda = (.65 - .39)m \Rightarrow \lambda = 0.52\,m$. Finally, from $v = f\lambda$ we find that $\lambda = \frac{v}{f} = \frac{343}{0.52} = 659.6\,Hz$. If one checks, this problem deals with the 3rd and 5th harmonics.
25. **D…** Using the ratio of Newton's Law of Gravitation to Coulomb's Law, we have $\frac{F_g}{F_e} = \frac{Gmm/r^2}{kqq/r^2} = \frac{Gm^2}{kq^2} = \frac{6.67\times10^{-11}\left(1.67\times10^{-27}\right)^2}{9\times10^9\left(1.6\times10^{-19}\right)^2} = 8\times10^{-37} \approx 10^{-36}$
26. **B…** Field lines point into negative charges and out of positive charges. Hence, q_2 is negative. Further, the number of lines from the charge is a measure of the charge magnitude. This means that $q_2/q_1 = -6/9 = -2/3$
27. **B…** The power for a resistor is $P = V^2/R$, so to increase the power, the resistance must be reduced. As resistance is $R = \rho\frac{L}{A}$, increasing the length, decreasing the area or increasing the resistivity all INCREASE the resistance. The only option listed decreasing the resistance is found through increase the diameter of the wire.
28. **A…** If the potential energy is negative, then positive work is required to disassemble the system. If the potential energy of the system is positive, positive work was required to set the system up. The work done by the external agent goes into the potential energy of the system. The potential energy of a system of charges can be zero if constructed with the appropriate combination of positive and negative charges.
29. **C…** As all bulbs are identical, the power (related to brightness) is most useful as $P = I^2R$, so the resistor with the most current will be brightest. As bulb C has the same current as that through the battery, while the branches with bulbs A,B, and D are in parallel and have the total current split between the branches, the current through bulb C is greatest.
30. **E…** A shorting wire across a bulb will short the bulb out… the shorts put into this circuit cross no bulbs and in fact have NO effect to the circuit. All the bulbs receive some current.
31. **B…** Maxwell's contribution to Ampere's Law was the realization that a time-changing electric field generated a magnetic field. We call the term related to the time-changing electric flux a displacement current.
32. **B…**.
33. **C…** Since FCD shorts bulb #3, the circuit is equivalently wires BC and EF in parallel. As the voltage across each branch must be equal to the voltage of the battery, the voltage from E to F is unchanged by closing the switch. Initially, there is voltage across the switch and after it is closed, the voltage is across the resistor. By closing the switch, the current in the circuit increases (a new branch with current) and the power from the battery must increase.

34. A… Increasing the resistance causes a decrease in the current on the left. This reduces the field strength for the solenoid $B = \mu_0 nI$. By the right-hand rule, the field through the solenoid is directed to the RIGHT. Hence, in the right-hand circuit, since there will be fewer field lines directed to the right, there is an induced electric field that will produce a current in the wires to "replace" the lost field lines. This means that current will be directed with the same orientation as the current in the left circuit … the ammeter needle will deflect to the LEFT.

35. D… By drawing a free body diagram, there are two forces acting: a gravitational force and a buoyant force. Since neither object accelerates and the gravitational forces are equal, this means that there are identical buoyant forces.

36. E… $F = PA = (1.0\times10^5\,Pa)(22m * 5m) = 1.1\times10^7\,N$

37. B…

38. E… Absolute zero is the temperature at which the energy of a material is minimized.

39. A… The first energy results in $Q = \left(\frac{3}{4}m\right)L$. The contribution of energy melts the remaining material and then increases the temperature. That is, $Q = \left(\frac{1}{4}m\right)L + mc(40^0)$.

Equating the energy, $\frac{3}{4}mL = \left(\frac{1}{4}m\right)L + mc(40^0) \Rightarrow \frac{1}{2}L = c(40^0) \Rightarrow \frac{L}{c} = 80^0$

40. C… An isochore is a process of constant volume. So, with the pressure decreasing, the temperature must decrease from the ideal gas law. By the First Law of Thermodynamics, $\Delta U = Q + W$, there is no work done (no change in volume) and the internal energy decreases (internal energy of an ideal gas is dependent on temperature). Hence, there IS a transfer of energy through heat with the system, making C incorrect. The rms speed of the gas molecules is proportional to the square root of the temperature (which decreased).

41. D… By definition of torque, one computes it as $Fd\sin\theta$ where the angle between the axis from which we are measuring to the direction of application of the force is 120 degrees.

42. E… The electric field in the interior of conductors in equilibrium is zero. Since the charge of +Q was on the surface of radius R, then all of the charge –Q on the outer conductor will be on the inner surface of radius 2R. Consequently, there is no electric field from 2R to infinity and from 0 to R. Hence, the electric field only exists between R and 2R with the field strongest at B (the field drops off like that of a point charge). In addition, the electric potential is zero at all points from infinity to C, at which point the magnitude increases up to point B (in the region of field). From zero to R, there is no electric field and hence no change in potential. Answer E is correct.

43. B… One way to solve this is to do the math… $p \approx -2f$ giving

$1/{-f} = 1/{-2f} + 1/q \Rightarrow q = -2f$. Since this is a virtual object (appearing on the left side), then a real object and a virtual image appear on the RIGHT side of the lens… This corresponds to the figure in B. One can also trace the rays using the rules for ray tracing… an interesting result is that a virtual object with a diverging lens in this case will act just like a real object with a converging lens. This is most closely represented by the ray diagram in B.

44. E… The wave speed depends on factors of tension in the string and its composition. Hence, since the wave speed is unchanged, with an increased frequency, there is a decreased wavelength $(v = f\lambda)$.

45. E... The rate of energy radiated is $P = \sigma A e T^4$ … hence doubling the temperature results in an increase in the time-rate of energy radiated by $2^4 = 16$.

46. A… Using the relation for entropy, $\Delta S = \frac{Q_r}{T} \Rightarrow Q_r = T\Delta S = 750\,J$. By the First Law of Thermodynamics and the fact that there is no change in temperature (and hence no change in the internal energy of the ideal gas), $\Delta U = Q + W \Rightarrow 0 = Q + W \Rightarrow W = -Q = -750\,J$

47. C… Einstein's Second Postulate of Special Relativity states that the speed of light is the same for all observers in an inertial frame. Hence, regardless of which way the green light is directed, the observer records that the light travels at speed c

48. D… $L_I = L_p\sqrt{1-\frac{v^2}{c^2}}$ so by squaring, $\frac{1}{4} = 1 - \frac{v^2}{c^2}$. Rearranging yields $\frac{v^2}{c^2} = \frac{3}{4} \Rightarrow v = \sqrt{\frac{3}{4}}c = 0.87\,c$

49. C… The deBroglie wavelength is $\lambda = \frac{h}{p}$. Since the kinetic energy is the same, we write $KE = \frac{p^2}{2m} \rightarrow p = \sqrt{2mK}$. Hence, $\lambda_1/\lambda_2 = \frac{h/\sqrt{2m_1K}}{h/\sqrt{2m_2K}} = \frac{\sqrt{2m_2K}}{\sqrt{2m_1K}} = \sqrt{m_2/m_1}$

50. A… Letting the gas decay for one time constant results in 3678 particles of gas in the sample using $N = N_0 e^{-t/\tau} = (10000)e^{-1} = 3678$. Adding in more gas gives a total of 13678 particles, meaning $10000 = 13678e^{-t/\tau} \Rightarrow \frac{10000}{13678} = e^{-t/\tau} \rightarrow t = -\tau \ln\left(\frac{10000}{13678}\right) = (0.313)\tau$