Passage 1

1. C. The separation of the plates is unchanged, so the electric field increases by a factor of 9.

2. B. According to the first equation, the electric field and the plate separation are inversely related, so an increase in *d* results in a decrease in *E*, so that B is the answer. If this is unclear, solve for *E* in the first equation.

3. B. For this question we need to remember that a helium nucleus has two protons (its atomic number on the periodic table), so the bare helium nucleus has twice the charge of a proton. Thus the force on it is twice as great.

4. B. if the separation of the plates increases by a factor of 2, then the electric field decreases by a factor of 2. And the force on the proton decreases by a factor of 2.

5. A. the voltage *V* and electric field *E* are proportional, so *A* is correct. For C to be correct, the equation would be to be $V = Ed + V_o$.

Passage 2

6. D. Since *r* is in the denominator, if *r* decreases, then the force increases. If *r* changes by a factor of 2, then the force changes by a factor of $2^2 = 4$.

7. B. The distance *r* is multiplied by 1.25. Thus *F* is multiplied by $1.25^{-2} = (4/5)^2 = 0.8^2 = 0.64 = (1-36/100)$. The force decreases by 36%.

8. D. Concerning choice A, a factor of 4 in both q_1 and q_2 will result in a factor of 16 in *F*, so this choice is incorrect. If *F* is to stay the same, and q_2 increases, then the distance *r* must increases, so choice Bi s incorrect. A factor of 4 in q_2 is equivalent to a factor of 2 in *r,* since $2^2 = 4$. Another way to see this is to solve for *r*, which you should do if this discussion was unclear.

9. D. If the charge on one ball increases by a factor of 4 (from 2 C to 8 C), then the force must increase by a factor of 4.

10. C. We can eliminate A and B immediately, since *F* decreases as *r* increase. We can eliminate D, since *F* does not have a linear relationship with *r* (that would look like $F = kr + c$). As *r* approaches 0, the force becomes infinite, so C is a good choice. Also, as *r* becomes large, *F* approaches 0 but never reaches it.

11. B. If both balls acquire a charge *q*, then the force between them is given by $F \frac{kq^2}{r^2}$, which is equivalent to $F = ar^2$, a quadratic equation. Thus the answer is B.

Passage 3

12. B. In order to determine *n,* we need two experiments where everything stays the same except for the area, so that we can investigate the results of a change in area. As for choice A, the object changes and the area does not, so that is out. In choice B, area changes from 1.5 to 3.0 cm^2, and nothing else changes, so B is correct. Choice is incorrect because the velocity is the only thing that changes. In choice D, both A and v change, so we would not be able to tell how much change in F is due to A and how much is due to v.

13. D. In the previous solution. We realized that experiments 4 and 6 have the property that all the input variables stay the same except for velocity v, which increases by a factor of 4. The force increases by a factor of 16, which means that p must be 2. That is, if p is 2, then an increase by a factor of 4 in v results in an increase by a factor of 4^2 in the force.

14. B. In choice A, experiments 1 and 2 both use a cork ball. For choice C, many input variable are altered between experiments 1 and 6, so it is impossible to isolate the effect of object density. As for choice D, experiments 4 and 6 both use a steel ball. Choice B involves two experiments in which only the density of the object changes.

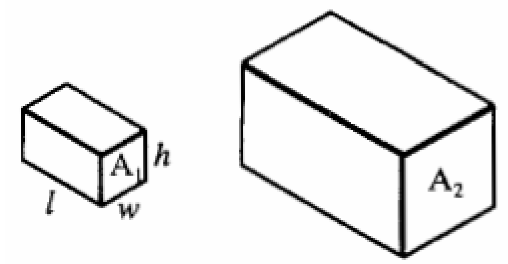
15. A. As for choice A, experiments 1 and 2 could be used to determine p, since the velocity changes and nothing else does. Once p is determined, k can be determined by substituting in values from either experiment 1 or 2. Thus experiments 1 and 2 are sufficient. We can exclude choices B and C (not minimum sets). As for choice D, there is not enough information to obtain p or k.

Passage 4

16. B. If v increases by a factor of 2, then the required energy increases by a factor of $2^2 = 4$.

17. C. If Julie increases her speed by 20%, then she multiplies her speed by 1.2. Thus the required energy is multiplied by $(1.2)^2 = 1.44$, which is an increase of 44%.

18. B. Comparing Scott's car to Laura's, all the linear dimensions are increased by a factor of 2 (see figure). The cross-sectional area A is width times height ($A = hw$), so if both h and w increase by a factor of 2, then A increases by a factor of 4. Thus the required energy increases by a factor of 4. the increase in length does not matter.



19. C. Julie increases her speed by a factor of 55/50 = 1.1, so the energy increases by a factor of $1.1^2 = 1.21$. This is an increase of 21%.

20. C. The easiest way to do this is to solve for D, giving $D = \frac{2E}{\rho_{air} A v^2}$. If A is reduced by 20%, then A is multiplied by 0.8. According to the above equation, D is multiplied by $(0.8)^{-1} = 1.25$, representing an increase by 25%.

Passage 5

21. A. The initial velocity is just that at the beginning of the experiment.

22. B. the average velocity is $v_{avg} = \Delta x / \Delta t$. The net displacement is $\Delta x = 1.35$ m – 1.35 m = 0 m.

23. D. This question consists entirely of words, but let us write an equation anyway. Uniform acceleration means a is constant, and $a = \Delta x / \Delta t$. Thus Δv and Δt are in a constant ratio. If one of the choices expresses this fact, then that would be the solution. (If not, we will have to think some more, perhaps find another equation.) Dis the correct answer.

24. D. We apply the definition of acceleration: $a = \frac{v_2 - v_1}{\Delta t} = \frac{0.6\frac{m}{s} - 0.6\frac{m}{s}}{1s} = 1.2\frac{m}{s^2}$.

25. A. Since acceleration is positive, the vector points in the forward direction (according to the sign convention of the passage).

26. B. for any 0.5 –s interval in the chart, the acceleration $(\Delta v / \Delta t)$ is a constant 1.2 m/s^2, even for the intervals near t = 1.5 s, where the velocity is zero. Thus B is the best answer.

Passage 6

27. B. We apply the formula
$$\Delta x = v_1 \Delta t + 1/2a(\Delta t)^2 = (0m/s)(4s) + 1/2(10m/s^2)(4s)^2 = 80m$$

28. B. the equation which involves change in velocity Δv and time is the definition of acceleration: $g = \frac{\Delta v}{\Delta t}$, $\Delta v = g\Delta t$, $\Delta v = g(t_2 - t_1)$.

29. C. Since velocity starts at zero, we can eliminate D. the instantaneous slope for the graph of v versus t must be a constant g = 9.8 m/s^2. The graph to which this applies is C.

30. B. Let's be clear about this by writing an equation. The equation involving Δv is the definition of acceleration (see solution to problem 2 above). Thus $\Delta v = g\Delta t$. The acceleration g is constant, and Δt is the same for the two situations (both have $\Delta t = 1$ s). Thus Δv is the same. The velocity increases at a constant rate throughout the fall.

31. A. We can calculate the height at the four clock readings:

$$\Delta x(t = 1s) = v_1\Delta t + \frac{1}{2}a\Delta t^2$$
$$= (0\frac{m}{x})(1s) + \frac{1}{2}(10\frac{m}{s^2})(1s)^2$$
$$= 5m$$
$$\Delta x(t = 2s) = 20m,$$
$$\Delta x(t = 3s) = 45m,$$
$$\Delta x(t = 4s) = 80m.$$

Thus from 1 to 2s, the object falls 15 m, while from 3 to 4 s, the object falls 35 m. this confirms our intuition that the distance fallen is greater for the later time interval. Notice the difference between this problem and the previous one.

32. D. We use the equation involving Δx, Δt, and the acceleration (since we know its value):

$$\Delta x = v_1\Delta t + \frac{1}{2}g\Delta t^2.$$

We have $v_1 = 0\frac{m}{s}$, so we write $\Delta x = \frac{1}{2}g\Delta t^2$.

If the time interval Δt increases by a factor of 3, what happens to Δx? Apparently it increases by a factor of 9.

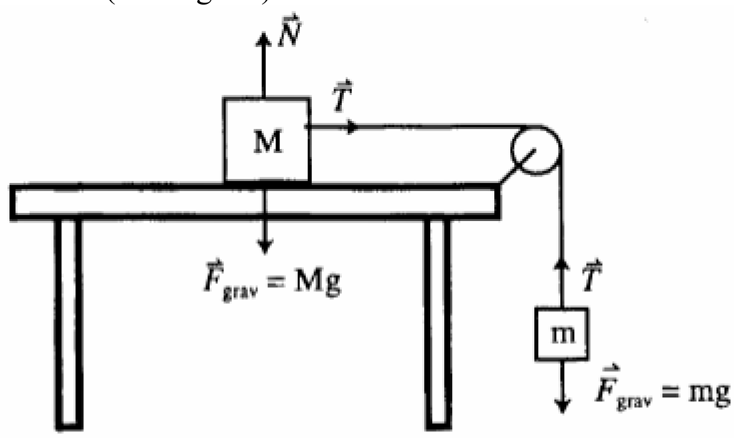
33. C. Choice A is nonsense. Choice B is a true statement, but it cannot be an adequate explanation for the fact, since the lead and iron balls fall at the same rate, and the force of gravity is presumably different on those two balls as well. Choice C is a good candidate, since the passage mentions air resistance as a caveat. Choice D is irrelevant.

Passage 7

34. D. Choice A and B are irrelevant, and comparisons, such as those in choice C, are meaningless if the units do not match. The correct choice is D. from the table we can see that equal jumps of time (for example, 0.2 s to 0.4 s) result in equal jumps of velocity (0.1 m/s to 0.2 m/s). This is consistent with the statement that $\Delta v / \Delta t$ is a constant, or that acceleration is constant.

35. B. It seems as if acceleration would be a useful quantity to calculate, so let's choose the interval from t = 0.0 to 0.2 s, obtaining $a = \Delta v / \Delta t$ = (0.1 m/s – 0.0 m/s) / (0.2 s – 0.0 s) = 0.5 m/s^2. Now we can look at the interval from t = 0.0 s to 0.9 s. We want to find Δx, and we have Δt = 0.9 s, v_1 = 0.0 m/s, and a = 0.5 m/s^2. From this we calculate $\Delta x = ½\, a(\Delta t)^2 \approx 0.20$ m.

36. B. Gravity certainly acts on *m*. the only thing touching mass *m* is the string, so B is correct. (See Figure.)



37. B. The things touching mass *M* are the table and the string. It is true that the tension in the string is, in some sense, caused by mass *m*, but *M* does not know or care what the other end of the string is connected to. It only cares that there is a force due to a string which is directed to the right.

38. C. By definition, we have $v_{avg} = \Delta x / \Delta t = (0.09m - 0.0m)/(0.06s - 0.0s) = 0.15m/s$.

39. C. Only the table and the string are touching mass *M*, but the string has no tension in it, so the answer is C.

Passage 8

40. D. For the student running along the roof, he starts from rest (v_1 = 0 m/s) and ends up running v_2 = 5 m/s. We have Δx = 5 m, and we want Δt. We use $\Delta x = 1/2(v_1 + v_2)\Delta t$ to obtain Δt = 2s.

41. B. The acceleration on the roof is one problem; the falling is another. For Δt, we need the vertical information:

$\Delta y = -7.2m$,

$a_y = -10\frac{m}{s^2}$,

$v_{1y} = 0\frac{m}{s}$,

$\Delta t = ?$

We use the equation $\Delta y = v_{1y}\Delta t + \frac{1}{2}a_y \Delta t^2$ to obtain $(\Delta t)^2 = 1.44\ s^2$. We can eliminate choice A, and choice C is too large, so B is right

42. B. We know gravity pulls down and the roof pushes up, and these forces add to zero. In addition, there must be a force accelerating the student forward (to the right). Surprisingly, it is the roof which exerts the force forward. His feet push backwards on the roof, and the roof (by the third law of motion) pushes forward on him.

43. A. We know gravity pulls down. Since nothing else touches the student, there is no other force.

44. D. Since the student's fall takes $\Delta t = 1.2$ s, the horizontal displacement is $\Delta x = v_{1x}\Delta t + 1/2 a_x (\Delta t)^2 = 6m$.

45. B. All during the fall the student has the same horizontal velocity 5 m/s.

Passage 9

46. A. We estimate density as follows:

$$\rho = \frac{m}{V}$$
$$= \frac{m}{\frac{4}{3}\pi r^3}$$
$$= \frac{2.0 \times 10^{30} kg}{4(1.4 \times 10^4 m)^3}$$

Here we have estimated $\pi = 3$. Next we estimate $1.4^3 = 1.4 \cdot 1.4 \cdot 1.4 = 2 \cdot 1.4 = 3$, so we have

$$\rho = \frac{10^{30}}{2 \cdot 3 \cdot 10^{12}} \frac{kg}{m^3}$$
$$= \frac{10}{6} \cdot 10^{29-12} \frac{kg}{m^3}$$
$$= 1.6 \times 10^{17} \frac{kg}{m^3}.$$

The arithmetic is spelled out so that you can see how you can do a lot of fast estimating and still get a reasonable answer. Even on questions which involve much less arithmetic, you should always be looking for shortcuts.

47. C. The acceleration due to gravity is given by $a_g = \frac{GM}{r^2}$, where M is the mass of the body, and r is the radius. The passage states that M for a neutron star is the same as M for the Sun, but r is 50,000 times smaller. That means a_g is greater by a factor of $(50,000)^2$.

48. A. The force due to gravity is $F_{grav} = \frac{GMm}{d^2}$, where G is the gravitational constant. Considering the two situations in the problem, we know the mass of the neutron star is the same as the mass of the Sun. The mass of the two planets is the same. The distance d is the same for the two situations. The force of gravity does not depend on the size of the bodies but on the distance from center to center.

49. B. Choice A is not relevant to the things which happen 2000 km away from the neutron star. Concentration choices C and D, the surface gravity of the neutron star is also irrelevant. Choice B correctly states that the force of gravity between near things is greater than between far things. This difference is enough to pull a body apart.

Passage 10

50. B. Each day the man travels a distance given by the circumference of the Earth $C = 2\pi R_{Earth}$.

51. C. in order to calculate the centripetal force $F_{cent} = ma_{cent}$, we need the mass of the man and the centripetal acceleration. We can find the centripetal acceleration $a_{cent}=v^2/R_{Earth}$ if we know his velocity and the radius of the Earth. It seems that D is the correct answer. The problem with choice D is that we can calculate the velocity once we know the period and radius (as in the previous problem).

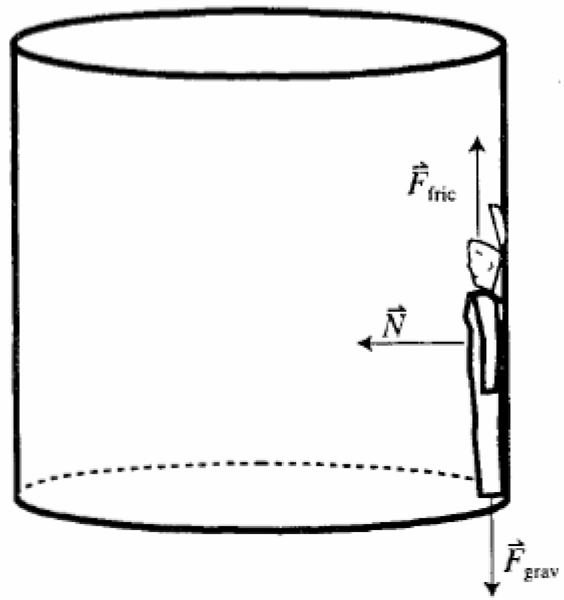
52. D. Since the man is traveling in a circle at constant speed, his acceleration vector points toward the center of rotation, and so does the net force vector. For this to be so, the magnitude of the gravitational force must be greater than the magnitude of the force of the ground.

53. A. the gravitational force for the two men is the same. Since the scale reading on a rotating Earth is less than the gravitation force, the correct answer is A.

54. C. According to Newton's law of gravitation, if the distance in the denominator is less, then the gravitational force is greater.

Passage 11

55. A. We draw a force diagram including the force of gravity.



The only thing touching the rider once the floor drops is the side of the drum, which exerts a normal force that ends up being toward the axis of rotation. It also exerts a frictional force, which is up (balancing gravity). For uniform circular motion, we know the net force must be toward the center of rotation, so we can see that this force diagram is complete.

56. A. From the diagram we can see that the normal force provides the centripetal force.

57. A. Because the motion is uniform circular rotation, the acceleration vector points toward the center of rotation.

58. C. The rider traverse the circumference of the circle ($2\pi R$) during each period of time T. Thus his speed is $2\pi R/T$.

59. A. the upward force must balance the gravitational force, so the magnitude of the upward force must be Mg as well.

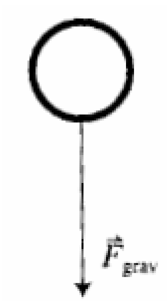
60. D. The force of friction (which is the upward force in the previous question) must be less than the maximum possible static friction $(F_s)_{\max} = \mu_s N$:

$Mg < \mu_s N$

But N is the centripetal force, so we substitute $N = Mv^2/R$ to obtain $Mg < \mu_s (M \frac{v^2}{R})$. Dividing both sides by M and multiplying by R/v^2 gives $gR/v^2 < \mu_s$. Translating this into words gives choice D.

Passage 12

61. A.



If there is no air, then the only force is the force of gravity: $(F_{net})_y = F_{grav}$. But the force of gravity is mg, and the acceleration is given by $ma_y = mg$, $a_y = g$. So, if we call "up" positive, then $a_y = -10$ m/s^2, and $v_{1y} = 3$ m/s. Also, to obtain the height, we write

$$v^2_{2y} = v^2_{1y} + 2a_y \Delta y$$

$$0 = (3\frac{m}{s})^2 + 2(-10\frac{m}{s^2})\Delta y,$$

$$\Delta y = 0.45m$$

62. B. We calculate the drag $F_{drag} = (0.2)(1.3kg/m^3)(\pi(0.03m)^2)(3m/s)^2 = 7\times10^{-3}N$.

63. C. According to the passage, the air resistance must be small compared to the other forces in the situation, but this is just the force of gravity.

64. A. As the ball travels away from the center of the Earth, the force of gravity decreases slightly, since $F_{grav}=Gm_1m_2/r^2$.

65. A. If air resistance is included, there is an initial force down while the ball is going up, so the maximum height is less. The ball loses energy to air resistance, so its speed just before hitting the ground will be less than in the idealized problem.

66. C. Even if the density of air changed appreciably (it does not), it would not help cats survive a greater all. This holds for choice B as well. Regarding choice C, if cats stretch their legs, then this increases their cross-sectional area, which would decrease their terminal velocity, so is a viable possibility for an answer. Regarding D, the statement is true, but the fact would not help a cat to have a lesser terminal velocity from a greater fall.

Passage 13

67. B. Don't let the information in the problem distract you from the fact that there must be a force balance on the muscle, since the muscle is not accelerating. Thus the magnitudes of $F_{forearm}$ and $F_{shoulder}$ are the same.

68. C. Stress, force, and area are related by the equation $\sigma = \frac{F}{A}$. The force exerted at the center of the biceps is the same as the force exerted at the forearm (force balance, see previous question), and the area is 100 times smaller. Thus the stress at the forearm is 100 times larger. (You may have done this problem by an intermediate step by calculating that force to be 500 N.)

69. D. Statue B has 8 times the volume of statue A. since $m=\rho V$, statue B has 8 times the mass. Since weight $w=mg$, statue B has 8 times the weight as well.

70. B. Stress is force/area. The force (weight) increases by a factor of 8, and the area increases by a factor of 4, so the stress increases by a factor of 8/4 = 2. Also, see the last sentence of the fourth paragraph.

71. C. The passage indicates that the breaking point is related to the threshold stress for the material in the cable. Stress is force per area. Increasing the length does not change the force of the load (the lantern weight) or the cross-sectional area, so the breaking weight would be the same.

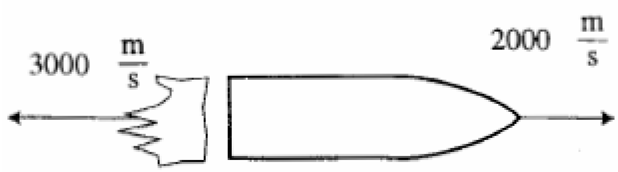
Passage 14

72. C. Both the second and third laws of motion concern unbalanced forces. But the third law of motion states that, if the ship exerts a force on the gas, then the gas exerts an equal and oppositely directed force on the ship, so C is correct.

73. C. Choice A is a true statement: Neon is not a product of uranium fission, but neither is hydrogen. The passage says that hydrogen is heated and then expelled. This is different from conventional rockets in which the products of the reaction themselves are expelled. Choice B is a true statement but also irrelevant, because the hydrogen does not react chemically in this process either. Concerning choice C, let's think of exhaust velocity. It is related to temperature and molecular mass of the exhaust gas. Since neon is more massive, the exhaust velocity will be less, and the thrust will be less. Choice C is correct.

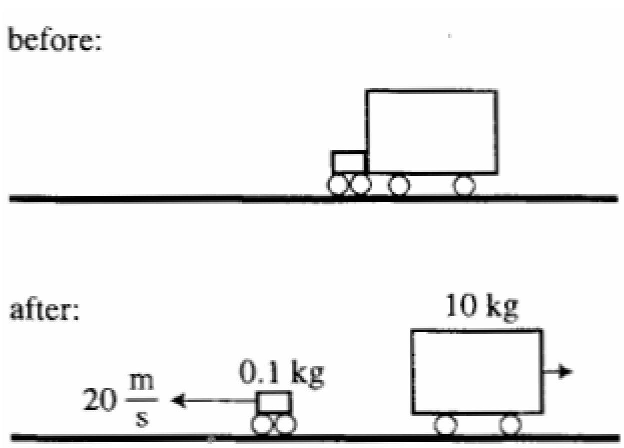
74. D. According to the passage, the hydrogen can not be heated fast enough. This would result in a low mass expulsion rate.

75. D. It helps to visualize this problem if we draw a diagram (see figure).



From the figure we can see that, relatives to the ship, the gases are going 5000 m/s.

76. A. Let's draw a diagram of the system.



77. B. This problem asks about force, and since a time is given in the problem, we immediately think to write $\Delta \vec{p} = \vec{F}_{net} \Delta t$. We know how to calculate the impulse Δp of the ship during the explosion, Δp = (10 kg)(0.2 m/s) – 0 = 2 kg m/s. Thus F = (2 kg m/s)/0.2 s = 10 N.

Passage 15

78. B. It is true there are more particles on the left side of the reaction, but that would tend to make the pressure go down, not up, so A is false. The pressure goes up because the temperature goes up, so B seems a good choice. Spontaneous reactions can have either an increase or a decrease in pressure, so C is incorrect. D is incorrect for the same reason.

79. C. The amount of work done is $W = F\Delta x \cos\phi = (P_{burn}A)(l)(1) = P_{burn}Al$. The quantity ΔH_{rxn} is given in Joules per mole of reactants going across the reaction equation, that is, per mole of O_2. Thus the amount of energy used is $n\Delta H_{rxn}$.

80. B. The first answer we think of is number ratio, since the coefficient in a reaction refers to the number of atoms/molecules/formula units or whatever. But that is not a choice. Mass ratio is wrong, so A is excluded. For ideal gases, volume ratio is proportional to number ratio, and since the reactants are gases, B is a good choice. C is nonsense. D is irrelevant since the reactants are the same temperature.

81. D. one of the reactants would be in excess. The heat of reaction is unchanged, so A is false. The combustion would still ignite, so B is out. The answer is C or D. If any of the intermediates in the reaction were stable compounds, then some of those compounds could end up in the waste gas. But the reaction of hydrogen with water is clean, and the waste gas would contain only leftover hydrogen or oxygen.

82. A. if the reaction were performed isothermally, then the number of gas particles would be less after the reaction than before the reaction. Since pressure at a given volume and temperature is proportional to the number of gas particles by the ideal gas law, the pressure would decrease.

83. A. When the gases are introduced in the chamber, the ideal gas law is $P_{atm}AL = n_{tot}RT_{amb}$, where n_{tot} is the number of total moles of both gases. Only one third of those molecules are oxygen, so A is correct.

84. A. We have assumed that the piston movement is small and the pressure stays about the same. If the piston movement were larger, the increase in volume would decrease the pressure. The gas in the chamber is doing work against the piston, so the internal energy of the gas must decrease. The temperature must decrease as well.

Passage 16

85. C. When the car goes from point C to point D, the only forces acting on it are gravity and the normal force. The normal force does no work, so we can use the simple statement of the conservation of energy. The initial kinetic energy is very small, so
$E_{P2} + E_{K2} = E_{P1} + E_{K1}$,
$E_{K2} = MgH_1$.

86. C. In order to obtain the velocity, we use the above equation and set kinetic energy to ½ Mv^2.

87. C. The situation is the same for the car going from point C to F as it is in going from C to E. The only forces ever operating are gravity and the normal force so the simple statement of energy conservation works:

$$E_{K1} + E_{P1} = E_{K2} + E_{P2},$$

$$0 + MgH_1 = \frac{1}{2}Mv^2 + MgH_2,$$

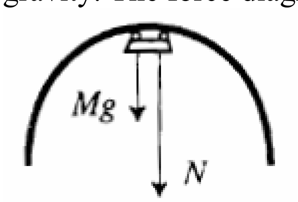
$$v = \sqrt{2g(H_2 - H_1)}.$$

88. A. The normal force never does work. This is because its direction is normal to not only the surface but to the motion of the object as well.

89. D. Gravity, certainly, is acting down. The only thing touching the car is the tracks, which provide a normal force, down. Thus gravity and the normal force together provide the centripetal force. So if we are counting forces, there are two. If you chose C, you need to review the section about the first law of motion.

90. D. This is analogous to the books in the car in Section 5. D, which get "pulled" toward the door when the car turns. No such thing happens, of course. The books are going in a straight path and the car's door turns into their path. In this case, the blood would be going along a straight path, but the body is pulled a centripetal force (from gravity and the normal force) away from the blood.

91. C. A glance at the answers shows expression which look like centripetal force and gravity. The force diagram is shown.



Gravity and the normal force add to make the net force, which is centripetal and leads to the acceleration of the car. On the one hand we can write $F_{net} = N + Mg$. On the other we write $F_{net} = Ma_{cent}$. Thus

$$N + Mg = M\frac{v_F^2}{R},$$

$$N = M\frac{v_F^2}{R} - Mg.$$

This is close. Now we need to remember that the radius of the circle R is half the diameter, which is H_2, so the answer is C.

92. C. The friction on the tracks plays no role in our current analysis and plays only a small role in reality. Since A is not a likely answer, let's look at the others. The bumpers are used to stop the car at the end of the ride, and they rely on friction. If the coefficient of friction is reduced, this could be disastrous. The cars are stopped by rubbing past the bumpers, so the friction is kinetic. By reducing the mass, the park operators reduce the amount of force necessary to negatively accelerate the cars to a stop.

93. A. The energy in the motor certainly starts out as electrical. If the bumpers dissipate the energy, then the energy ends up as heat. In the ride itself, energy is sloshed back and forth from kinetic to potential.

Passage 17

94. C. The definition of kinetic energy involves mass and velocity, and we know either, so A and B are not right. Choice C mentions force, and there is a connection between force and energy, the equation $W = F\Delta x \cos\phi$. Does this equation apply in this case? The change in kinetic energy is given by the total work done on an object, that is $F_{net}\Delta x \cos\phi$, so the equation does apply. The quantity Δx is the length of the barrel, and we have $\cos\phi = 1$.

95. C. Pressure and temperature go together in the ideal gas equation, and though we may have the volume of the "reaction flask", we do not have the number of moles, so A is not the answer. It seems difficult to connect velocity with pressure, so let us look for a better answer than B. Pressure and force together remind us of the definition of pressure $P=F/A$. Since we have the cross-sectional area of the cannon, this is a connection between force and pressure. C is the answer.

96. A. The rate of reaction does depend on surface area, concentration, and temperature, but grain size affects only the surface area. So A is the answer. Only a catalyst could reduce the activation energy.

97. B. The energy starts as chemical energy and turns to heat after burning. The whole point of a cannon is to convert energy to kinetic energy of the ball. Note that the conversion of heat to kinetic energy is inefficient. Among the choices given, however, B is the best answer.

98. B. The energy starts as chemical energy and turns to heat after burning. The whole point of a cannon is to convert energy to kinetic energy of the ball. Note that the conversion of heat to kinetic energy is inefficient. Among the choices given, however, B is the best answer.

99. D. This is like a problem we have done before. Because of the following calculation:

$E_{K1} + E_{P1} = E_{K2} + E_{P2}$,

$\frac{1}{2}mv^2 = mgh$,

$h = \frac{v^2}{2g}$,

we see that we do not need anything besides the ball velocity upon leaving the cannon.

Passage 18

100. A. Well, points P_1 and P_2 are in the water, and P_2 is above P_1, so the pressure at P_1 should be greater by ρgh. It is confusing, though, since the pressure at P_1 must be P_{atm}. The air just above P_2 must have pressure P_{atm}. Usually the pressure on one side of a boundary between two substances is the same as the pressure on the other side, but this is not true if the boundary is curved, as when a meniscus forms.

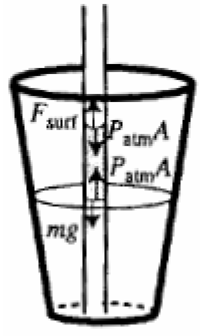
101. C. Certainly there are pressure forces, but these balance (both are $F = P_{atm}\pi r^2$). The surface tension pulls the column up, balancing the force of gravity.

102. C. The pressure at the top of the column is given by $F = PA = P_{atm}\pi r^2$. We use the air pressure since it is the air that exerts the downward force on the column.

103. C. The force due to gravity is $F_{grav} = mg = \rho Vg = \rho\pi r^2 hg$.

104. C. The length of the line of contact is the circumference of the straw, so $L = 2\pi r$.

105. B. The force diagram for the column of water is shown.



Since nothing is accelerating, the force equation becomes the following:

$$P_{atm}A + F_{surf} - P_{atm}A - mg = 0,$$

$$F_{surf} = mg,$$

$$2\pi r\gamma = \pi r^2 h\rho g,$$

$$h = \frac{2\gamma}{r\rho g}.$$

From this we see that height *h* increases proportionally as *r* decreases.

Passage 19

106. B. In this model a maximum height is obtained by setting the pressure at the top of the column to zero. Thus, $P_{bottom} = P_{top} + \rho gh$ becomes $P_{atm} = 0 + \rho gh$. Thus $h = P_{atm} / \rho g = 10^5 Pa /(10^3 kg / m^3)(10m / s^2) = 10m$.

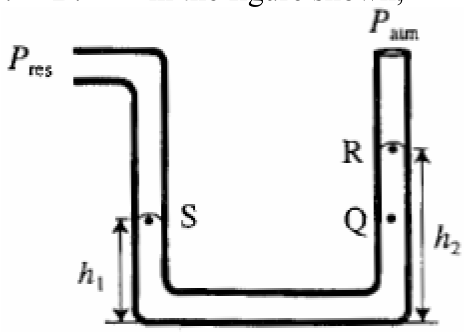
107. D. According to this equation, the height *h* depends only on the atmospheric pressure, the density of the fluid, and the acceleration due to gravity.

108. C. The passage mentions that the surface tension and the gravitational force must add to zero. Thus, $2\pi r\gamma - \rho\pi r^2 hg = 0$ (as in the previous passage). This becomes $h = 2\gamma / r\rho g = \dfrac{2(0.072\frac{N}{m})}{(2\times 10^{-7} m)(10^3 \frac{kg}{m^3})(10\frac{m}{s^2})} = 72 meters$

109. A. In this model the height is inversely proportional to the radius.

Passage 20

110. B. in the figure shown,



the pressure at point Q is the same as the pressure at point S, the reservoir pressure (Pascal's law). Hydrostatic equilibrium dictates that $P_Q = P_{atm} + \rho g(h_2 - h_1)$.

111. D. The pressure all along the flow is the same, except for the tiny region where Barometer 2 disturbs the flow. Thus the pressure measured by Barometer 1 is the same as the upstream pressure. If we take the streamline shown in the figure, then upstream we have pressure P_1 and desired velocity v, and at the point in front of the barometer we have pressure P_2 and $v = 0$. Bernoulli's equation becomes

$$P_1 + \frac{1}{2}\rho v^2 = P_2 + \frac{1}{2}\rho(0)^2,$$

$$v = \sqrt{\frac{2(P_2 - P_1)}{\rho}}.$$

112. C. Since the flow must go through a smaller area, the velocity must increase to maintain the same flow rate $f = Av$.

113. A. Bernoulli's equation (neglecting the gravity terms) is $P_3 + \frac{1}{2}\rho {v_3}^2 = P_4 + \frac{1}{2}\rho {v_4}^2$. If v_4 is greater than v_3, then P_4 is less than P_3. but do not rely on the equation; remember that for flow along a streamline, the pressure increases when the velocity decreases.

114. B. If the fluid is incompressible, then $f = A_3 v_3 = A_4 v_{4new}$, regardless of viscosity. Thus v_{4new} is the same as v_4.

115. A. Bernoulli's equation can no longer be used to obtain pressure, but perhaps we can figure out the answer by figuring out where the equation breaks down. The equation is a statement of energy conservation. If viscosity is added, then viscosity converts some energy into heat. Thus, we have

$$P_3 + \frac{1}{2}\rho v_3{}^2 = P_4 + \frac{1}{2}\rho v_4{}^2 + \frac{heatenergy}{volume}.$$

Comparing this with the equation in problem 4 above, we see that in this equation P_4 must be smaller (the $\frac{1}{2}\rho v_4{}^2$ term is the same; see previous problem). The key to this problem is remembering that Bernoulli's equation is about energy. Viscosity robs the flow energy creating heat, thus reducing pressure from the prediction given by the Bernoulli equation.

Passage 21

116. C. Our first thought is to use the information about linear density, but there is no way to find the tension in the string. What other formula do we have for wave velocity? Well, $v = \lambda f$, and we know f = 660 Hz. We can get the wavelength just by knowing that the note 660 Hz refers to the fundamental. The fundamental has a wavelength λ=2(0.65 m) = 1.3 m.

117. A. For the D string we can use λ = 1.3 m, so that $f = v/\lambda$ = 294 Hz. We do not have to do the calculation. If we look at the choices, we see only one choice less than 382.

118. C. The fourth harmonic has a wavelength λ = ½ (0.65 m) = 0.325 m, yielding $f = v/\lambda$ = 1175 Hz.

119. C. The first node occurs one fourth of the way from the neck end. Since the neck is a node as well, there must be a node at the midpoint and three fourth of the way down. This corresponds to a wavelength 0.325 m, as in problem 3 (above).

120. A. The sixth harmonic has five nodes (not including the ends). This is shown in the figure. The wavelength is λ = 1/3 (0.65 m) = 0.22 m.

121. D. Increasing the frequency by 3% is the same as increasing it by a factor of 1.03, which means increasing the wave velocity (recall $v = \lambda f$, and λ does not change) by a factor of 1.03. Now $T = v^2\mu$, and μ does not change, which means T is increased by a factor of $(1.03)^2 \approx 1.06$, which is an increase of 6%.

Passage 22

122. D. We apply $v = \lambda f$, using the speed of sound in air.

123. D. According to the first paragraph, the wavelength must be smaller than the observed object. A wavelength of 10^{-3} m corresponds to a frequency of about 1.5 x 10^6 Hz in biological tissue, where we use v = 1500 m/s.

124. A. The lowest frequency is 20 Hz, so $T = 1/f = 1/(20\ Hz) = 0.5\ s$.

125. D. The two real choices are B and D. Since there is tearing and rupturing involved, there must be chemical bonds broken, so D is t.

126. D. Frequency is not directly connected to intensity. Amplitude and intensity are connected, but amplitude is not mentioned among the choices.

127. D. Choices A and B are irrelevant. Concerning choice C, the problem Is not energy reflecting off the organ but being absorbed by it. This is an example of resonance, and there must be a weak coupling between two oscillators: the sound is one and the oscillating organ is the other.

128. D. The equation here is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}},$$

$$k = m(2\pi f)^2$$

$$= (0.5kg)(2\pi\frac{1}{0.2})^2$$

$$\approx (\frac{1}{2})(2 \cdot 3 \cdot \frac{10}{2})^2\ \frac{N}{m}$$

$$\approx 450\frac{N}{m}.$$

Passage 23

129. B. According to paragraph 1, the wavelength must be shorter than the target insect. Thus the frequency must be greater than $f = v/l_{\text{insect}}$ = 34300 Hz = 34.3 kHz.

130. B. The sound pulse must travel from the bat to the insect, be reflected, and travel back again, for a total of 6 m. The time required is $\Delta t = \Delta x / v = 0.027$ s.

131. B. Since the insect and the bat are moving in the same direction at the same speed, there is n Doppler shift, and the detected frequency is simply 30 kHz.

132. C. Higher harmonic content refers to higher frequencies being present in addition to the fundamental. These higher harmonic frequencies thus have shorter wavelength. This would not really aid in distance measurement, so choice A is incorrect. Stunning the insect? Choice B is also incorrect. There is a sentence in paragraph 1 which indicates that C is plausible, since shorter wavelengths are more likely to be reflected if the wavelength of the fundamental is too large. If the harmonics are Doppler shifted, then so is the fundamental, so choice D is incorrect.

133. D. If the tree could detect a frequency, it would detect $f_{tree} = \frac{343}{343-15} 50kHz$.
If it re-emitted this frequency, then the bat would detect a frequency given by
$f_{\det} = \frac{343+15}{343} f_{tree} = \frac{358}{343}\frac{343}{328}(50kHz) \approx 55kHz$.
There are two Doppler shifts.

You do not need to do the calculation to obtain the answer. Given the fact that the bat and the tree approach each other. The frequency must be increased, so D is only possible answer.

134. B. The bat does not hear frequencies which are too far from those it sends out. Choice D is definitely not right, but it is interesting to think why. Why I such an adaptation completely useless?

Passage 24

135. B. This is the definition of interference. Diffraction is the spreading of waves. Beats is a particular phenomenon which occurs when waves of similar frequency interfere. Difference tones have to do with the way the ear processes sound.

136. C. The passage says that a note of average frequency turns on and off. Thus the perceived frequency is (30.87 Hz + 32.70 Hz)/2 = 31.79 Hz.

137. B. This question asks for the beat frequency (times per second), so f_{beat} = 32.70 Hz – 30.87 Hz = 1.83 Hz.

138. C. Choices A, B, and C all share the property that the difference is the desired frequency 110 Hz, but choice D is excluded. Choices A and B include frequencies lower than 110 Hz, which cannot possibly be harmonics, so A and B are incorrect.

139. B. The pressure in the room does not change markedly from the equilibrium pressure. Sound is tiny variations of pressure. If the vertical axis were marked $\Delta P + P - P_{eq}$, then an answer like A would be appropriate.

140. C. According to paragraph 3, sound of two frequencies f_1 and f_2 enter the ear. Choice A is definitely wrong, especially with a wavelength drawn onto the graph. For that the horizontal axis must be a space coordinate like *x*. Choice B might show a portion of the power spectrum after some processing, but the frequency $f_1 - f_2$ does not enter the ear. The ear constructs the difference tone later. Choice C is correct. Choice D might have been correct if time were the horizontal coordinate.

Passage 25

141. B. Since Alice is an equal distance from the speakers, and the speakers are emitting sound waves in phase, wave crests arrive at her location in phase. Thus she is at an antinode. Bob has moved to a position of relative silence, which must be a node.

142. C. The waves arrive out of phase where Bob is sitting, because the wave from the left speaker takes a bit longer to arrive. When a crest from the right speaker is arriving, the corresponding crest from the left is still in transit. By the time it arrives, a trough is arriving from the right speaker.

143. D. The sum of the two distances is not significant and cannot be derived from the information.

144. D. The key here is that, for Bob, the waves arrive out of phase. When crest is coming from the left speaker, trough comes from the right. The difference is half a wavelength.

145. C. Alice is positioned equidistant from the speakers, so for her the waves will still be in phase, so A and D are incorrect. Bob's location at a node depends on the wavelength of the sound, which we change when we change the frequency.

146. C. Experiment 2 is the prescription for creating beats.

Passage 26

147. C. This is an application of the equation
$f = c/\lambda = (3\times10^{8}\, m/s)/(520\times10^{-9}\, m) = 5.8\times10^{14}\, Hz.$

148. C

$$m = -\frac{d_i}{d_o} = -\frac{0.025m}{0.25m} = -0.1.$$

Since the magnification is -0.1, the size of the image is (0.1)(0.01 m) = 10^{-3} m and inverted.

149. A. The subtended angle can be calculated from information in the third paragraph, that is, the ratio of the spatial separation of the top and bottom of the moth to the distance form the moth to the eye. Thus the angle is 0.01 m/0.25 m = 0.04 radians, which is about 2.3º.

150. D. The desired power of the combination of corrective lens plus eye lens is 1/0.025 m = 40 D. Since $P_{combo} = P_{eye} + P_{correct}$, we must have $P_{correct}$ = 5 D.

151. A. The red light focused on the retina. This lens refracts the blue light more than red light and hence focuses blue rays in front of the red focus. The figure exaggerates the case.

152. D. According to the passage, if the camera is diffraction limited, then the resolution depends on the size of the lens (that is, light gathering hole) and the wavelength of the light used. Choices A, B, and C address neither of these issues. Increasing the size of the entire camera would increase the size of the lens, which would increase the resolution, by decreasing the resolution angle.

153. B. Trying to determine if two dots are separate or blurred is analogous to trying to distinguish two headlights, so the information is in paragraph 3. The resolution of the eye is the ratio of dot separation to standing distance, so we write

$$2 \times 10^{-4} = \frac{0.002m}{D},$$

$$D = 10m.$$

You must stand 10 m away.

154. A. The best resolution we can hope for is diffraction limited, for which $\theta_{diff} = \lambda / d = (520 \times 10^{-9} m)/(2.4m) = 2 \times 10^{-7} rad$. We have used green light as being representative of visible light.

155. C. UV light has a shorter wavelength than visible light, so the diffraction angle $\theta_{diff} = \lambda / d$ would decreases, giving a better resolution, assuming the apparatus is diffraction limited.

156. D. Concerning choice A, a larger pupil does allow in more light, but this does not explain a decrease in resolution. For choice B, the opposite is true: a larger pupil allow more directional information to enter the eye, which should improve resolution if there were not another factor present. For choice C, both cats and humans contend with chromatic aberration. The large lens introduces spherical aberration, so D is correct.

Passage 27

157. A. The frequency of the radiation is the same as the frequency of the alternating current, 10^7 Hz. The wavelength of the radiation is $\lambda = c / f = (3\times10^8 m/s)/(10^7 Hz) = 30m$. For a quarter-wave antenna (see paragraph 3), the length would be 7.5 m.

158. D. According to the passage, the electric field "points along the same axis as the current" that produces it. Since the antenna is vertical, the current it carries is vertical, so the electric field is vertical as well.

159. B. The magnetic field is perpendicular to the direction of propagation (north/south) and to the electric field (up/down). So the magnetic field must point east/west.

160. B. The electric field points up and down, so the force on the electrons in the antenna is up and down as well. The elections should be free to move in this direction if an alternating current is to be set up. Thus the antenna should be vertical.

161. B. When you thin of an electric field, you should immediately think of force on a charge. Choice B is correct in that the force creates the current. (Choice C is incorrect because the electrons are not bound to individual atoms.)

162. A. The energy starts as electrical.

Passage 28

163. A. A sodium ion (Na^+) is positively charged, and the negatively charged central wire will attract it.

164. A. it does not matter what kind of molecule this is. The only thing that matters is its neutral charge. The passage states that it will be attracted to the wire.

165. D. Since this question is about energy and charges, our guess is that we will use $W = q\Delta V$ somewhere. A fluoride ion near the negative wire has high potential energy, so it gains kinetic energy as it moves away from the wire. The change in potential energy is $q\Delta V = (-1.6\times10^{-19} C)(5\times10^4 J/C) = -8\times10^{-15} J$. (Recall: a fluoride ion has one extra electron, so its charge is the same as an electron.) The increase in kinetic energy is thus 8 x 10^{-15} J, since energy is being conserved. Now some energy may be lost to heat, and so on, so this is actually the maximum energy available..

166. B. The main formula we have for capacitance is $C = Q / \Delta V$, which may tempt you to think that an increase in potential would lead to a decrease in capacitance, but this is not so. The capacitance of a device is fixed by the construction of that device, and the amount of stored charge goes up proportionally as the potential. An increase in potential would result in an increase in the charge on the wire Q_{wire}, but the capacitance remains the same.

167. C. The only thing we can do with the new piece of information is to combine it with the information in the third paragraph, to obtain the power usage of $P = (300J / m^3)(100m^3 / s) = 3 \times 10^4 Watts$. The question asks for current, and the only connection we know of between power and current is potential difference. Aha! $I = P / \Delta V = (3 \times 10^4 J / s)/(5 \times 10^4 J / C) = 0.8C / s$.

168. D. The electric field lines point away from the positive charge and towards the negative charge.

169. D. The attraction of neutral particles to a charged wire is like a charged comb attracting neutral pieces of paper. Choice A does not refer to charges at all. Choice B involves two charged particles, and Choice C involves two neutral species. Choice D refers to a charged and a neutral species, just like the wire and the pollutants. A charge is induced on the pollutants, and the resulting net force is attractive.

Passage 29

170. D. Choice A represents the positron decay, which is forbidden for subtle quantum reasons. Choice B represents normal beta decay, which does not happen for this nucleus. Choice C does not have balanced subscripts. Choice D fits the description in the question.

171. B. According to the passage, K-capture happens under the same condition which promotes positron decay, that is, proton-rich nuclei. That is to say, nuclei with more protons with more protons than neutrons have a negative *N-Z.I*

172. B. According to the passage, the possibility of electron capture is non-zero only if there is some overlap of the electron wave function and the nucleus, so if the orbital has vanishing amplitude near the nucleus, the probability of capture is small.

173. C. Choice A is incorrect because the neutrino hardly interacts with matter (see paragraph 2). The whole point of K-capture is to turn one of the many protons into a neutron, so the neutron is not likely to change back, and choice B is incorrect. Since K-capture pulls an electron from the innermost shell, that orbital empty and can be filled by another electron from outer shells. This is accomplished by emitting photons, so choice C is a possibility. There is no positron created, so Choice D is incorrect.

174. A. During normal beta decay, a neutron goes away (N decreases by 1) and a proton appears in its place (Z increases by 1). The net effect is *N-Z* decreases by 2.

175. C. During alpha decay, both *N* and *Z* decrease by 2, so *N-Z* stays the same.