Physical Sciences MCAT Practice Items (AAMC)

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<u>Q 1</u> D P2, L5-6; PHY 7.1.2

We are told that a practical depth of penetration (d) is 200 times the wavelength (λ) of the incident ultrasonic waves or d = 200 λ. We are given the depth (0.20 m) and so the wavelength of our incident wave is:

$$d = 200\,\lambda \rightarrow \lambda = d/200 = 0.20\text{ m}/200 = 2/2000 = 1/1000\text{ m}$$

Using velocity (v) = frequency (f) $\times$ wavelength (λ), we can find the maximum frequency. We just found λ to be equal to 1/1000 m, and the question gives v = 1 500 m/s, so the calculation is as follows:

$$\boxed{v = f\lambda}$$

$$\rightarrow f = v/\lambda \rightarrow f = 1{,}500\text{ m/s} / (1/1000\text{ m}) \rightarrow f = 1{,}500 \times 1000$$
$$\therefore f = 1.5 \times 10^6\text{ Hz}$$

Therefore, answer choice **D.** is correct.

<u>Q 2</u> A P1, L3-5

The easiest part of this answer is the final type of energy. The transducer feeds a signal into a monitor that displays an electronically constructed picture, eliminating answer choices **B.** and **C.** Sound waves represent a mechanical form of energy because the waves vibrate the medium through which they are transmitted, making answer choice **A.** correct.

<u>Q 3</u> C P4, L2-5

The beat frequency represents the absolute value of the difference between the incident and the reflected frequency. The passage states that this phenomenon also occurs when waves of two separate frequencies from two separate sources (in this case, that from the trumpet and that from the piano) mix. This means that the absolute difference between 512 Hz (the frequency of the piano) and any frequency of the trumpet must equal 4 Hz. Therefore, the trumpet could have produced a frequency 4 Hz above or below the note of the piano:

$$512 \text{ Hz} \pm 4 \text{ Hz} = 508 \text{ Hz and } 516 \text{ Hz.}$$

<u>Q 4</u> C PHY 1.5

The tricky part of this question is determining the amount of time taken for the wave to travel from the surface to the reflecting interface. If it took 4.0×10^5 s to travel to the reflecting interface and back to the starting position, then it took half that time to reach the interface (2.0×10^5 s).

Using distance (d) = velocity (v) × time (t):

$$\boxed{d = v \times t}$$

$$\rightarrow d = 1\,500 \text{ m s}^{-1} \times 2.0 \times 10^{-5} \text{ s} \rightarrow d = 3\,000 \times 10^{-5} = 3 \times 10^3 \times 10^{-5}$$

$$\therefore d = 3 \times 10^{-2} \text{ m}$$

Therefore, answer choice **C.** is correct.

<u>Q 5</u> B P1, L6-7; PHY 7.1.2

The passage states that the ultrasonic wavelength must be equal to or smaller than the size of the object. Since frequency and wavelength are inversely related ($f = v/\lambda$) and speed is constant, the lowest wave frequency will correspond to the maximum wavelength, which in this case will be equal to the size of the object.

Using $v = f\lambda$, where $v = 1{,}500\ m\ s^{-1}$ and $\lambda = 10^{-3}$ m:

$$v = f\lambda$$

$$\rightarrow f = v/\lambda \rightarrow f = 1{,}500\ m\ s^{-1}/10^{-3}\ m \rightarrow f = 1.5 \times 10^3/10^{-3}$$
$$\therefore f = 1.5 \times 10^6\ Hz$$

Therefore, answer choice **B.** is correct.

Q 6 B **PHY 8.2**

Going from one medium to another generally does not affect the frequency of a wave, and so answer choices **C.** and **D.** can be eliminated. Common sense will tell you that the shape of an object should not cause waves to be reflected. The differing densities of different mediums affects the velocity of a wave. For instance, sound waves can travel faster through liquids than through gases. When the velocity of a wave changes, so does the wavelength ($v = f\lambda$), and reflection occurs.

Q 7 D **T1; PHY 2.2, 7.2.1**

Recall Hooke's Law:

Restoring Force (F) = spring constant (k) × displacement from equilibrium (x).

When there is no mass on the spring, the natural length of the spring is L = 0.400 (T1). This is the equilibrium reference point. For Trial 2, $x = 0.405 - 0.400 \rightarrow x = 0.005$ m. The restoring force is always in the opposite direction of the displacement (to push it back toward equilibrium). In this case, gravity pulls the mass toward the ground until the restoring force of the spring is equal to the force of gravity and the mass stops moving. Therefore, F = mg. Since, from above, F = -kx:

$$mg = -kx$$

$$k = -0.1\ kg \times 10\ m\ s^{-2}/\ 0.005\ m \rightarrow k = -1\ N\ /\ (5/1000)\ m \rightarrow k = 1000/5$$
$$\therefore k = 200\ N/m$$

Therefore, answer choice **D.** is correct.

Q 8 B **P3, L5-8; PHY 5.3/4/5**

Since maximum potential energy occurs at maximum recoil distance, the question can be answered by finding the Trial in which the spring has the highest potential energy. In this experiment, the kinetic energy of the mass is completely converted into potential energy when the spring is maximally compressed (and for a moment, there is no movement). Therefore the mass with the highest kinetic energy will have the highest potential energy and hence, the greatest recoil distance.

Using Kinetic Energy (E_k) = ½ mv^2 , where m = mass, v = velocity, we can compare the kinetic energy for each trial. Since we are comparing the relative values of E_k, we do not need the (½) constant in the equation.

$$\text{Trial 1: } E_k = 1 \times 5^2 = 25$$

$$\text{Trial 2: } E_k = 2 \times 4^2 = 2 \times 16 = 32$$

$$\text{Trial 3: } E_k = 3 \times 3^2 = 3 \times 9 = 27$$

$$\text{Trial 4: } E_k = 4 \times 2^2 = 4 \times 4 = 16$$

$$\text{Trial 5: } E_k = 5 \times 1^2 = 5$$

In Trial 5 there is the highest E_k, and so the spring will have the highest maximum potential energy (when all of its kinetic energy is converted to potential energy) and thus, the greatest recoil distance.

<u>Q 9</u> D PHY 7.1.2

The period (T) is the duration of one cycle of vibration and corresponds to the inverse of the frequency (f). If we are comparing f values, we can simplify our equation by removing the constants; the only variable in the equation is the mass, since k is a property of the spring and the same spring is used in all trials of Experiment 2.

$T = 2\pi\ (m/k)^{1/2}$ simplifies to $T\ \alpha\ m^{1/2}$, where α means "proportional to." Substituting f = 1/T in the equation, we obtain $f\ \alpha\ 1/T$ and therefore, $f\ \alpha\ 1/m^{1/2}$. To get the comparison, we set up a ratio of this equation:

$$f_1/f_4 = (1/1^{1/2})/(1/4^{1/2}) \rightarrow f_1/f_4 = (1/2)$$

$$\therefore f_1/f_4 = 2$$

If $f_1/f_4 = 2$, then $f_1 = 2f_4$. Therefore, answer choice **D.** is correct.

<u>Q 10</u> C PHY 7.2.1

From Hooke's Law, we know that simple harmonic motion is described by a restoring force, F = -kx. This force is described by the expression in answer choice **C.**

You can also use elimination. Force is measured in newtons ($1\ N = 1\ kg\ m/s^2$) and k is measured in N/m (*see* Q7).

$$\text{Units for answer choice } \mathbf{A.} = kx^2/4 = (N/m)\ (m^2) = N\ m$$

$$\text{Units for answer choice } \mathbf{D.} = kx^2 = (N/m)\ (m^2) = N\ m$$

Answer choices **A.** and **D.** can be eliminated because we are looking for a force, and the units of force are newtons (N), not newton-meters (N m).

The equation in answer choice **B.** was probably included to confuse those who have the potential energy equation on the brain, and thus may see the "½" part of it and jump.

Q 11 A deduce; Ap A.4.2

The passage tells us that $E_p = ½\ kx^2$. Since k is a constant, E_p is proportional to x^2. Therefore, as the spring is compressed to x_{max}, the E_p versus x graph is an exponential curve described by $y = x^2$.

Q 12 D PHY 7.2.1/2

The spring constant for two springs attached to the same mass in parallel is obtained by adding the k's of the individual springs:

$$k_{system} = k_1 + k_2 \rightarrow k_{system} = 12 + 12$$

$$\therefore\ k_{system} = 24\ N/m$$

Therefore, answer choice **D.** is correct.

Q 13 A PHY 2.2, 7.2.1; deduce

The force (F) added by the extra mass is $F = mg = (3)\ (10) = 30\ N$.
Using Hooke's Law (and the k value found in Q7):

$$\boxed{F = -kx}$$

$$\rightarrow x = -F/k \rightarrow x = -30/200 \rightarrow x = -3/20$$
$$\rightarrow x = -(3/2)\ (1/10) \rightarrow x = 1.5/10$$
$$\therefore x = 0.15\ m$$

Therefore, answer choice **A.** is correct.

Q 14 D P2, L1-2

The passage states that compressional waves travel by vibrating the medium in the direction in which the wave is traveling, a motion described by answer choice **D.**

Q 15 B P2, L1-2

If the wave travels by vibrating particles, then it follows that the wave would be unable to travel in a vacuum, which is void of particles.

Q 16 A P2, L1-2; CHM 4.1.2

Ultrasonic vibrations traveling through a medium cause the particles to vibrate, thereby creating heat. Recall that kinetic energy (e.g. movement, vibration) of molecules is accompanied by an increase in temperature, so an increase in vibration of molecules will lead to an increase in temperature.

Q 17 A P3, L2-3

The blood is shown flowing towards the Doppler stethoscope. As stated in the passage, this will cause an increase in the frequency of the reflected wave.

Q 18 B P4, L4-5; PHY 7.1.2

The wavelength of the wave must be no larger than the object of interest.
Using velocity (v) = frequency (f) × wavelength (λ):

$$v = f\lambda$$

$$\rightarrow \lambda = v/f \rightarrow \lambda = 1.5 \times 10^3 \text{ m s}^{-1}/3.0 \times 10^5 \rightarrow \lambda = (3/2)/3 \times 10^3/10^5$$
$$\rightarrow \lambda = \tfrac{1}{2} \times 10^{-2} \rightarrow \lambda = 0.5 \times 10^{-2}$$
$$\therefore \lambda = 5 \times 10^{-3} \text{ m}$$

Since the wavelength should be no larger than the object of interest, the object should be the same size as the wavelength, 5×10^{-3} m.

Q 19 B PHY 11.3

Answer choices **A.** and **D.** cannot be correct because a real image produced by a curved mirror is always inverted while a virtual image is always erect.

We use the equation $1/i + 1/o = 1/f$, where i = image distance, o = object distance and f= focal length. Keep in mind that for i and o, positive values mean real and negative values mean virtual. If the object is far away, then the term 1/o will be very small. We know that the focal length is positive for a concave mirror because the rays are converged in front of the mirror.

$$1/i + 1/o = 1/f$$

$$\rightarrow 1/i = 1/f - 1/o \rightarrow 1/i = \text{positive number - very small number}$$
$$\therefore 1/i = \text{positive number}$$

Therefore, since i is positive, the image is real (and inverted).

<u>Q 20</u> B **PHY 2.4, 3.3**

The Law of Gravitation describes the force between two bodies of mass, in this case, the earth and the telescope: $F = G\, M_eM_t/r^2$. The centripetal acceleration for the telescope, which is moving in uniform circular motion, is $a_c = v^2/r$. Gravity gives the telescope this acceleration and therefore the force keeping the telescope in orbit can also be described by Newton's Second Law:

$$F = ma$$

$$\rightarrow F = M_tg \rightarrow F = M_t\, a_c$$
$$\therefore F = M_t\, v^2/r$$

Now we have two equations for F. To obtain the orbital speed, we equate the two expressions:

$$G\, M_e\, M_t/r^2 = M_t\, v^2/r \rightarrow G\, M_e/r = v^2$$

$$\therefore v = (G\, M_e/r)^{1/2}$$

Therefore, answer choice **B.** is correct.

<u>Q 21</u> D **PHY 5.4**

Using Potential Energy (E_p) = mass (m) × gravity (g) × height (h):

$$E_p = 1.1 \times 10^4 \text{ kg} \times 10 \text{ m s}^{-2} \times 6.11 \times 10^5 \rightarrow E_p = 1 \times 10^4 \times 10^1 \times 6 \times 10^5$$

$$\therefore E_p = 6 \times 10^{10} \text{ (approximately)}$$

Therefore, answer choice **D.** is correct.

Q 22 C **P2, L3**

The equation for magnification is described in the first 3 lines of the question:
Magnification (M) = (focal length of the primary mirror)/ (focal length of the eyepiece)
The focal length of the primary mirror can be found in P2 and the focal length of the eyepiece is given in the question. The calculation is then straightforward:

$$M = 13\text{ m} / (2.5 \times 10^{-2}\text{ m}) \rightarrow M = (1.3 \times 10^{1})/(2.5 \times 10^{-2})$$
$$M = 1.3/2.5 \times 10^{1}/10^{-2} \rightarrow M = ½ \times 10^{3} \rightarrow M = 0.5 \times 10^{3}$$
$$\rightarrow M = 5 \times 10^{2} \text{ (approximately)}$$

$$\therefore M = 500$$

Therefore, answer choice **C.** is correct.

Q 23 A **PHY 9.2.4**

Here is the general trend of the electromagnetic spectrum:

Long wavelength (λ), low frequency (f), low energy (E) $\rightarrow$ Short λ, high f, high E

Radio $\rightarrow$ Micro $\rightarrow$ Infrared $\rightarrow$ Visible $\rightarrow$ Ultraviolet $\rightarrow$ X-Rays $\rightarrow$ Gamma Rays

Ultraviolet light is on the short wavelength, high frequency and high energy end of the spectrum. On this basis, answer choices **B.** and **C.** can be eliminated. To decide between the remaining choices, we have to assess if it is more likely that UV rays are absorbed or reflected by the atmosphere. Since there is no information in the passage concerning this, we can use our everyday knowledge about UV rays. The ozone layer, which is rapidly depleting because of pollution, serves to protect the earth from harmful UV rays by absorbing them (note that the ozone layer does not absorb visible light). Therefore, answer choice **A.** is correct.

Q 24 D **P1, L1-3, L13**

The chemically powered engines of Discovery allowed the shuttle to travel (kinetic energy) away from the Earth and release the telescope into orbit (gravitational potential energy).

Q 25 B **P1, L3; P1, L14**

Using Kinetic Energy (E_k) = ½ mass (m) × velocity^2 (v^2):

$$E_k = \tfrac{1}{2}(1.1 \times 10^4\,\text{kg})(7.8 \times 10^3\,\text{m/s})^2 \rightarrow E_k = \tfrac{1}{2}(1.1 \times 10^4\,\text{kg})(64 \times 10^6)$$
$$\rightarrow E_k = \tfrac{1}{2}(64 \times 10^{10}) \rightarrow E_k = 32 \times 10^{10}$$

$$\therefore E_k = 3.2 \times 10^{11}\ \text{J (approximately)}$$

Therefore, answer choice **B.** is correct.

<u>Q 26</u> C PHY 11.3

We can obtain the answer by using the same equation as in Q19: $1/i + 1/o = 1/f$.
For a distant object, we can approximate that o (the object distance) will be very large and that $1/o$ will approach zero. Substituting this in the equation:

$$1/i + 1/o = 1/f$$

$$\rightarrow 1/i + 0 = 1/f \rightarrow 1/i = 1/f$$
$$\therefore i = f$$

Therefore, for a distant object, the image will be at the focal point of the concave mirror.

<u>Q 27</u> A PHY 2.2

Using Newton's Second Law, Force (F) = mass (m) × acceleration (a):

$$F = ma$$

$$\rightarrow a = F/m$$

We can see that it is true that for heavier cars (large m) there is less acceleration for a given force, because a is inversely proportional to m. Answer choices **B.**, **C.** and **D.** can not be reasoned out using Newton's Second Law.

<u>Q 28</u> D deduce

Note that the problem is asking for forms of energy which result from the collision (i.e. after the collision). We know that the wall does not move, so it cannot have kinetic energy. This eliminates answer choices **A.**, **B.**, and **C.**, which all include kinetic energy of the wall as part of the answer. We are left with answer choice **D.**, which makes sense because some of the car's kinetic energy should be converted to heat when it is stopped by the wall, and some of it should be converted to elastic potential energy, and finally, some of the pieces will continue to move (e.g. have kinetic energy) when they break off.

Q 29 B PHY 1.4, 2.2

Once again, this answer can be reasoned out using Newton's Second Law, $F = ma$. Since the person's mass remains the same, the only way to decrease the force is by decreasing the acceleration. Using acceleration = velocity/time, we see that if the time of collision is increased, the acceleration is decreased and in turn, the force of collision is decreased. When the driver comes in contact with the steering wheel, its collapse will increase the time that the driver remains in motion with decreasing acceleration before the driver is finally forced to stop altogether.

Q 30 D PHY 6.1.2

Since Pressure (P) is defined as the force (F) per unit area (A), $P = F/A$, we know that pressure will be affected by a change in area of the seat belts, narrowing down our options to answer choices **C.** and **D.** If the seat belt is wider, then A increases and P decreases for a given force since P is inversely related to A. Therefore, the wider belt decreases the pressure felt by the passenger.

Q 31 A deduce

Since the total energy of the system is conserved, dissipation of the kinetic energy by pieces of the car breaking off will result in a decrease in kinetic energy involved in the collision itself. The equation for kinetic energy is $E_k = \frac{1}{2} mv^2$. When parts of the car break away, the mass of the bulk of the car is reduced, thereby reducing its kinetic energy. When the bulk of the car finally comes to a complete stop in the collision, its kinetic energy is transferred to the driver as the driver moves toward the windshield. Therefore, the driver will be safer in a car that loses some of its kinetic energy through pieces that break away during a collision, because it will have less kinetic energy to contribute toward propelling the driver into the windshield.

Q 32 C PHY 1.6; deduce

To minimize the severity of the impact, we want to minimize the acceleration (toward the windshield) felt by the driver during the collision. The inflexible car will have a quick collision because it will simply hit and stop (or perhaps recoil a bit). Since $a = v/t$ (*see* Q29), a small t (time of collision) will result in a larger acceleration felt by the driver. Conversely, a flexible car will be deformed during collision, thus making the collision last longer. The driver will experience less acceleration because of the longer collision.

Q 33 A PHY 4.4.1

To solve this problem, we use the principle of conservation of momentum:

momentum before the collision (p_1)= momentum after collision (p_2),

where p = mass (m) × velocity (v). An inelastic collision will result in the two cars traveling together in one direction after collision. Since momentum is conserved:

(momentum of car 1 + momentum of car 2) = (momentum of car 1&2)

Arbitrarily setting the direction East as positive, and letting $m_{1\&2}$ and $v_{1\&2}$ be the mass and velocity, respectively, of the two cars together after collision, we obtain:

$$(m_1v_1 + m_2v_2) = (m_{1\&2}\, v_{1\&2})$$

$$\rightarrow (1{,}000 \text{ kg} \times -10 \text{ m/s} + 1{,}500 \text{ kg} \times 8 \text{ m/s}) = (1{,}000 + 1{,}500 \text{ kg})v_{1\&2}$$
$$\rightarrow (-10{,}000 + 1{,}500 \times 2 \times 4) = 2{,}500\ v_{1\&2}$$
$$\rightarrow (-10{,}000 + 3{,}000 \times 4) = 2{,}500\ v_{1\&2} \rightarrow (-10{,}000 + 12{,}000) = 2{,}500\ v_{1\&2}$$
$$\rightarrow (2{,}000) = 2{,}500\ v_{1\&2} \rightarrow v_{1\&2} = 2{,}000 / 2{,}500 \rightarrow v_{1\&2} = 20/25$$
$$\rightarrow v_{1\&2} = 4/5 \rightarrow v_{1\&2} = 8/10$$

$$\therefore v_{1\&2} = 0.8 \text{ m/s}$$

Since this is a positive value, the cars are traveling East at a velocity of 0.8 m/s.

Q 34 A PHY 10.2

Watts are a measure of the power transformed by the electric device. Since both bulbs are drawing the same number of watts, they use energy at the same rate, eliminating answer choices **C.** and **D.** The difference must lie how the bulbs utilize this energy. The only plausible answer is that the incandescent light loses more energy as heat and consequently, has less energy left over to give off light.

Q 35 D P1, L1-2; P3, L6; PHY 7.1.2

Using our old friend: velocity (v) = frequency (f) × wavelength (λ), where v in this case equals the speed of light (c, given in the passage) and f = 60 Hz:

$$v = f\lambda$$

$$\rightarrow \lambda = v/f \rightarrow \lambda = 3 \times 10^8 \text{ m/s} /60 \text{ Hz} \rightarrow \lambda = 3 \times 10^8/(6 \times 10^1)$$
$$\rightarrow \lambda = 3/6 \times 10^8/10^1 \rightarrow \lambda = ½ \times 10^7 \rightarrow \lambda = 0.5 \times 10^7$$

$$\therefore \lambda = 5 \times 10^6 \text{ m}$$

Therefore, answer choice **D.** is correct.

Q 36 C P2, L3-5; PHY 10.2

The passage states that each electrical device receives the full 120 V, but only a portion of the current. Therefore, answer choices **B.** and **D.** can be eliminated. Now we must decide whether outlets are wired in series or in parallel. In a parallel circuit, components are wired such that there is more than one path for current to take in completing the circuit. In a two component circuit, current traveling from one component back to the emf source does not have to pass through the second component on the way. This ensures that the loss of function of one component does not break the circuit and affect the current supply of the other components. In a parallel circuit the total current is the sum of the current traveling in each path while the voltage is the same for all paths. When circuit elements are in series, there is only one path for current to take. In a two component circuit, current traveling from one component back to the emf source must pass through the second component. Loss of function of one component breaks the circuit, and all components are affected. In series circuits, the current is the same over each component while the total voltage drop is the sum of all the emf sources. In this example, the voltage that each outlet receives is the same (P2, L3-5), which means that the electrical devices are in parallel. It only makes sense that a house be wired this way, since it would not be practical to lose power to all electrical devices every time one of them breaks the circuit.

Q 37 C P1, L2; PHY 10.2

The equation for power (P) is: P = current (I) × voltage (V). The given current is 10 A and the voltage, obtained from the passage, is 120 V:

$$P = IV$$

$$\rightarrow P = (10)(120)$$
$$\therefore P = 1{,}200 \text{ W}$$

Therefore, answer choice **C.** is correct.

Q 38 B **deduce**

If the electromagnetic waves are reflected, refracted or diffracted, then the radiation will be rerouted from its original path without necessarily affecting the detector. Absorption by the detector will likely result in some change in the detector which will signal the presence of the waves.

Q 39 D **PHY 10.2**

Power is the measure of work performed per unit time and the unit of power is watts (W). Therefore, if we multiply power by an amount of time, we obtain the amount of work performed, which is a measure of the total energy transformed by the system. This is a simple matter of units:

$$\text{k W} \times \text{time}$$

Since watts, and thus kilowatts (k W), are a measure of work per unit time:

$$\text{work/time} \times \text{time} = \text{work}$$

Q 40 D **PHY 10.1/2**

To answer this question, we combine the equation for Power (P = IV) with Ohm's Law (V = IR) to eliminate I, a variable not provided in the question or the passage.

$$P = IV \rightarrow I = P/V$$

and

$$V = IR \rightarrow I = V/R$$

Equating the two values of I and solving for R, we obtain:

$$P/V = V/R \rightarrow R = V/(P/V) \rightarrow R = V^2/P \rightarrow R = 120^2/40$$
$$\rightarrow R = 14\,400/40 \rightarrow R = 1440/4$$
$$\therefore R = 360\ \Omega$$

Therefore, answer choice **D.** is correct.

Q 41 C **PHY 7.2.3**

In a normal swing, the bob will reach maximum speed at the lowest point of its arc, then it will start to slow down as it moves upward against gravity. If the bob is released from the string as it moves through the lowest point of its arc, it will have momentum toward the right and will be pulled down by gravity. Only answer choice **B.** accurately portrays this. You may be tempted to choose answer choice **A.** because this is what you would expect to happen if you did this in real life. However, this is only because of the difficulty of releasing the bob at exactly the moment when it is at its lowest point in the arc. If you let it go just as it begins the upswing, the momentum will be slightly upturned, and thus the bob would follow the path shown in answer choice **A.** Ideally, though, if you could release the bob at exactly the lowest point, there would be no upward momentum.

<u>Q 42</u> D P4, L5-6

Recall that Kinetic Energy = ½ × mass (m) × velocity^2 (v^2). If the speed of the combined bobs is less than the speed of the left bob before the collision, then the kinetic energy of the system has decreased. This type of collision is referred to as inelastic.

<u>Q 43</u> A PHY 4.4, 5.5

During a perfectly elastic collision, there is conservation of mechanical energy, where mechanical energy (E_t) = potential energy (E_p) + kinetic energy (E_k). In this system, the E_p of the left bob at a given height is transformed completely into E_k when the bob reaches the lowest point of the arc and comes into contact with the right bob. If the collision is elastic, the left bob comes to a stop after the collision, and all of the bob's E_k is transferred to the right bob. As the right bob swings up, its speed will decrease as its E_k is transformed into E_p. Once all of the E_k of the right bob is converted to E_p, it should reach the same height as that of the original position of the left bob, since it should have the same amount of energy as the left ball had.

<u>Q 44</u> C PHY 4.4

Since one bob bounces off the other, this is called an elastic collision. The elasticity refers to the collision, not the objects themselves, thereby eliminating answer choices **A.** and **B.** Furthermore, there is insufficient information to determine which bob is more elastic than the other. If an object collides with an identical object, there should be total transfer of kinetic energy, and the first object will stop while the second object moves away. This is not what happened and so we know the bobs were not identical. If the right bob weighed less than the left bob, the left bob would overpower it upon impact and both bobs would move to the right. Therefore, the left bob must have weighed less than the right bob.

<u>Q 45</u> B PHY 4.4

In an inelastic collision, there is conservation of momentum, not kinetic energy. Letting m_1 and v_1 be the mass and velocity, respectively, of the left bob, and m_2 and v_2 be the mass and velocity, respectively, of the right bob, we have:

$$\text{pre-collision momentum } (m_1v_1 + m_2v_2) = \text{post-collision momentum } (m_{1\&2}v_{1\&2})$$
$$\rightarrow m_1v_1 + m_2v_2 = m_{1\&2}v_{1\&2}$$

We know that $m_2v_2 = 0$ since the right bob is at rest before the collision, and that $m_{1\&2} = 2m_1$ because the balls are identical. We are left with:

$$m_1v_1 = 2m_1v_{1\&2} \rightarrow v_1 = 2\, v_{1\&2}$$

$$\therefore v_{1\&2} = v_1/2$$

Therefore, answer choice **B.** is correct.

<u>Q 46</u> C P2, L4-7; PHY 4.4, 5.5

This question is similar to Q43. In this elastic collision, the potential energy of the left bob will be transformed into kinetic energy as it descends, and then all of its kinetic energy will be transferred to the right bob upon impact (the left bob comes to a stop). Since all of the left bob's energy is transferred to the right bob, the right bob will move with the same speed that the left bob had before the collision. The kinetic energy of the right bob will be transferred to potential energy (the same amount the left bob had) as it swings upward, and it will rise to the same height that the left bob was at when it was released. We know that the right bob will rise to the same height that the left bob started at, and so if the left bob's initial height is increased by a factor of 2, the right bob's maximum height will also increase by a factor of 2.

<u>Q 47</u> A P3

Answer choice **D.** can be eliminated right away because the right bob is not moving prior to collision. Since this is an elastic collision, the total kinetic energy is conserved.. Since the right bob is moving after the collision, we know that the left bob has transferred some of its kinetic energy to it. The equation for kinetic energy is $E_k = ½ mv^2$, and the mass of the bob does not change, so the velocity must decrease in order for the kinetic energy of the left bob to decrease following collision. This supports answer choice **A.** Answer choices **B.** and **C.** are incorrect because if the left bob has equal or greater speed following the collision, it will also have equal or greater kinetic energy. This, coupled with the kinetic energy of the right bob (which had no kinetic energy prior to the collision), violates the conservation of kinetic energy in the system.

<u>Q 48</u> B deduce

The gravitational acceleration (g) of the bob is independent of the bob's mass. Therefore, the acceleration of the bob towards the lowest point of the arc in both cases will be the same and as a result, the time taken to reach the lowest point of the arc will be the same. This is similar to dropping two objects of different mass in a vacuum; they always reach the ground at the same time.

<u>Q 49</u> B PHY 10.2

Using Ohm's Law, V = IR, where I = 0.5 A. R can be determined by using the equation for the total resistance in a parallel circuit:

$$1/R = 1/R_L + 1/R_s$$

$$\rightarrow 1/R = 1/1 + ½ \rightarrow 1/R = 1 + ½ \rightarrow 1/R = 3/2$$
$$\therefore R = 2/3$$

Substituting the values into Ohm's law:

$$V = IR$$

$$\rightarrow V = (1/2)(2/3) \rightarrow V = 2/6 \rightarrow V = 1/3$$
$$\therefore V = 0.33 \text{ V (approximately)}$$

Therefore, answer choice **B.** is correct.

<u>Q 50</u> D P1, L1-2

Since we are using an electrical current to heat the water, then the temperature and the energy of the system are increasing. The entropy will increase because heat causes molecules to move around more (e.g. increase in kinetic energy) and thus have more "disorder." The power dissipated in R_L, defined by the equation $P = I^2R$, will remain constant since I and R remain constant.

<u>Q 51</u> A deduce

We know that the final step involves the heating of water, eliminating answer choices **A.** and **C.** The battery supplies electricity to the circuit through chemical processes, making answer choice **A.** correct.

Q 52 **C** **PHY 4.1.6**

$$PV = nRT$$

$$\rightarrow P = nRT/V$$

Using the ideal gas law, Pressure × Volume = number of moles × R (constant) × Temperature, we see that pressure and volume are inversely related.

Q 53 **B** **PHY 8.7**

Using the formula $Q = mc\Delta T$, where Q = heat or energy transferred, m = mass, c = specific heat and ΔT = change in temperature, we can calculate the energy transferred to the system.

$$Q = mc\Delta T$$

$$\rightarrow Q = 1 \text{ kg} \times 4.2 \times 10^3 \text{ J/ (kg °C)} \times 0.1 \text{ °C}$$
$$\therefore Q = 4.2 \times 10^2 \text{ J}$$

Using power (P) = energy (E)/time (t), where in this case E = q (from above), and P = 1.0 W (given in question), we have:

$$P = E/t \rightarrow t = E/P \rightarrow t = 4.2 \times 10^2 \text{ J} /(1 \text{ J s}^{-1})$$

$$\therefore t = 420 \text{ s}$$

Therefore, answer choice **B.** is correct.

Q 54 **B** **PHY 2.4**

We need to use the Law of Gravitation $[F = K_G(m_1m_2/r^2)]$. First we find the force of attraction between an object at the surface of the Earth and the Earth itself:

$$(1)\ F = K_G m_o m_e/r_e^2$$

Then we find the force of attraction between the same object at the altitude of the space station and the Earth:

$$(2)\ F = K_G m_o m_e/r_{(e+a)}^2$$

In equations (1) and (2), K_G is the universal constant of gravitation, m_o is the mass of the object, m_e is the mass of the Earth, r_e is the distance between the object and the center of the Earth (e.g. the radius of the Earth) and $r_{(e+a)}$ is the distance between the object and the center of the Earth (e.g. the radius of the Earth plus the altitude of the space station).

We are looking for the percentage of the force at the surface that is present at the altitude of the space station, so we divide (2) by (1) and cancel out as many variables as possible before entering the values:

$$(K_G m_o m_e / r_{(e+a)}^2) / (K_G m_o m_e / r_e^2) = (K_G m_o m_e / r_{(e+a)}^2) \times (r_e^2 / K_g m_o m_e)$$

$$\therefore r_e^2 / r_{(e+a)}^2$$

Entering the values for the radius of the earth and the distance from the center of the Earth to the altitude of the space station (both given in the passage), we have:

$$(6 \times 10^6)^2/(1.2 \times 10^7)^2 \rightarrow (6 \times 10^6)^2/(12 \times 10^6)^2 \rightarrow 36 \times 10^{12}/144 \times 10^{12}$$
$$\rightarrow 1 \times 10^{12}/4 \times 10^{12} \rightarrow 1/4$$
$$\therefore 25\%.$$

Therefore, answer choice **B.** is correct.

<u>Q 55</u> B PHY 3.3; deduce

The space station is traveling in a circular orbit around the Earth. The velocity of the space station is always in a direction tangential to the circular orbit, such that it is at a right angle to the gravitational force acting on the space station. Gravity pulls the space station straight toward the center of the earth. This force gives the space station its radial acceleration, and keeps the space station from traveling off on a tangent. If gravity is suddenly eliminated, momentum will project the space station along the tangential velocity vector. This situation is shown in answer choice **B.** Answer choice **A.** represents the normal path of the space station in orbit. Answer choice **D.** shows the space station moving in the direction of the gravitational force, which for this question is supposed to be absent. Answer choice **C.** is incorrect because the space station is being pulled in exactly the opposite direction of the gravitational force, not at a right angle to it.

<u>Q 56</u> B P1, L6-7; P2, L6; PHY 6.1.1

We use the equation Density (D) = mass (m)/volume (v). We can eliminate answer choice **A.** right away because it gives an answer in mass per unit area, not volume. The passage gives the mass of the sun and the formula for volume of a sphere ($v = 4/3\ \pi R^3$). Approximating π to 3, we have:

$$D = 2 \times 10^{30} / [(4/3\ \pi)(7.2 \times 10^8)^3] \rightarrow D = 2 \times 10^{30}/[(4/3 \times 3\ (7 \times 10^8)^3]$$
$$\rightarrow D = 2 \times 10^{30} / [4 \times (49 \times 7 \times 10^{24})] \rightarrow D = 2 \times 10^{30}/(4 \times (50 \times 7 \times 10^{24})$$
$$\rightarrow D = 2 \times 10^{30} / (4 \times 350 \times 10^{24}) \rightarrow D = 2/4 \times 1/350 \times 10^{30}/10^{24}$$

$$\rightarrow D = \frac{1}{2} \times 1/350 \times 10^{30}/10^{24}$$
$$\rightarrow D = 1/700 \times 10^{6} \rightarrow D = 1/7 \times 10^{6}/10^{2} \rightarrow D = 1/7 \times 10^{4}$$
$$\rightarrow D = 0.14 \times 10^{4}$$

$$\therefore D = 1.4 \times 10^{3} \text{ kg/m}^{3}.$$

Therefore, answer choice **B.** is correct.

Q 57 B PHY 2.2/4

By rearranging Newton's second Law ($F = ma \rightarrow a = F/m$), and substituting the equation for gravitational force, $F = K_G(m_1m_2/r^2)$, we obtain expression for acceleration of an observer of mass m_o at the surface of the earth (mass m_e):

$$a = K_G(m_em_o/r^2)/m_o$$

$$\therefore a = K_Gm_e/r^2$$

Note that $K_G = G$ in this question.

Q 58 C P1, L8-9

The passage indicates that the spherical surface of the Sun radiates 6.5×10^7 J of energy per square meter per second. Since the question is asking for the total amount of energy radiated from the surface, we must calculate the surface area of the sun (in square meters) and multiply it by the value given. Approximating π to 3, we have:

$$\text{Total Energy (E)} = \text{Area (m}^2) \times 6.5 \times 10^7 \text{ J m}^{-2} \text{ s}^{-1} \rightarrow E = 4\pi r^2 \times 6.5 \times 10^7$$
$$\rightarrow E = 4 \times 3 \times (7.2 \times 10^8)^2 \times 6.5 \times 10^7 \rightarrow E = 4 \times 3 \times (49 \times 10^{16}) \times 6.5 \times 10^7$$
$$\rightarrow E = 4 \times 3 \times (50 \times 10^{16}) \times 6.5 \times 10^7$$
$$\rightarrow E = (3 \times 6.5) \times (4 \times 50) \times (10^{16} \times 10^7) \rightarrow E = 20 \times 200 \times 10^{23}$$
$$\rightarrow E = 4000 \times 10^{23}$$

$$\therefore E = 4 \times 10^{26} \text{ W}.$$

Note that $1\text{W} = 1 \text{ J s}^{-1}$

Q 59 A PHY 1.5

We use the equation velocity (v) = distance (d)/ time (t). The distance in this case is the circumference of the circular orbit of the Earth around the sun. Circumference of a circle

= 2πr, and the radius of Earth's orbit is given in the question. Substituting 2πr for d, and approximating π to 3, we have:

$$v = d/t$$

$$\rightarrow v = 2\pi r/t \rightarrow v = 2\pi\,(1.5 \times 10^{11})/(3 \times 10^{7})$$
$$\rightarrow v = 3\pi \times 10^{11}/(3 \times 10^{7}) \rightarrow v = 3 \times 3 \times 10^{11}/(3 \times 10^{7})$$
$$\rightarrow v = (9/3) \times (10^{11}/10^{7})$$

$$\therefore v = 3 \times 10^{4} \text{ m/s.}$$

Therefore, answer choice **A.** is correct.

<u>Q 60</u> C P1, L1-3

The two forces controlling the vertical position of the plane are gravity, pulling the plane towards the earth, and the pressure difference above and below the wings, which produces the upward lift of the plane. If the plane is not moving vertically up or down (i.e. if the plane is in horizontal flight), then these two opposing forces must be equal. Therefore, the lift on the plane must be equal to the force of gravity, F = mg, which is the weight of the airplane. If the lift of the plane was zero, only gravity would be acting on the plane and it would crash!

<u>Q 61</u> B PHY 1.1

This question requires basic vector addition. Since the horizontal and vertical components are given, we can calculate the resultant speed using the Pythagorean theorum, since $v_{horizontal}$ and $v_{vertical}$ form a right triangle with $v_{resultant}$ as the hypotenuse. The calculation is as follows:

$$v_r^2 = v_h^2 + v_v^2 \rightarrow v_r^2 = 20^2 + 100^2 \rightarrow v_r^2 = (400 + 10{,}000) \rightarrow v_r^2 = 10{,}400$$
$$\rightarrow v_r = (10{,}400)^{1/2} \rightarrow v_r = (1.04 \times 10^4)^{½} \rightarrow v_r = 1 \times 10^2$$

$$\therefore v_r = 100 \text{ m/s (approximately)}$$

Since the actual value of $1.04^{1/2}$ is slightly higher than the approximation of 1 that was used, we can choose answer choice **B.** over answer choice **A.** Alternatively, you can skip the approximation and find that the square root of 1.04 is very close to 1.02, making the answer clearly 102 m/s.

<u>Q 62</u> D P1, L4; deduce

This question can be answered by looking at Bernoulli's equation:

Pressure (P) + density of the air (ρ) $\times$ airspeed^2 (v^2) = constant (C)

Isolating for pressure in, we have:

$$P = C/\rho v^2$$

Bernoulli's equation relates P and ρ such that if ρ increases, P decreases. Since the density of air decreases with increasing altitude, the plane at the lower altitude of 1 km will be traveling through air of higher density than the plane at 6 km. The plane at the lower altitude (higher density) will experience greater pressure.

{Note: the component of height *h* in Bernoulli's equation does not factor in to this problem since the difference in distance (*h*) between the top of the wing to the ground and the bottom of the wing to the ground is negligible (i.e. it is the pressure difference centered around the wing that creates the lift).}

<u>Q 63</u> B PHY 2.2; P2, L1-3

The 9,000 N force provided by the engines is opposed by an 8,000 N force of air friction. Assuming that the two forces act in exactly opposite directions, vector addition results in a net force of 1,000 N in the forward direction of the plane. Using Newton's second law, Force (F) = mass (m) $\times$ acceleration (a), we can calculate the acceleration of the plane:

F = ma

$$\rightarrow a = F/m \rightarrow a = 1000/300 \rightarrow a = 10/3$$
$$\therefore a = 3 \text{ m/s}^2$$

Therefore, answer choice **B.** is correct.

<u>Q 64</u> C deduce

In the absence of air resistance, gravity is the only force acting on the projectile. Since gravity affects the projectile in the vertical direction, the horizontal speed of the projectile is unaffected and will remain unchanged from its initial value.

<u>Q 65</u> D P2, L4-7

The passage indicates that the vertical component determines the time the projectile will be in the air while the horizontal component determines how far the projectile will travel per unit time. The projectile launched at 10° is given some initial vertical speed and consequently, it will travel for a longer period of time than the projectile given no initial vertical speed (launched horizontally). This leaves us with answer choices **B.** and **D.**

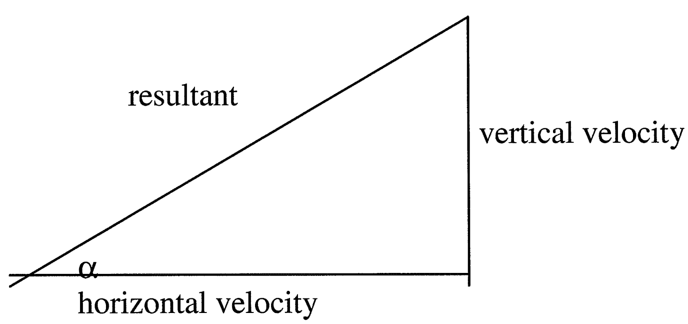
The two projectiles are given the same horizontal speed and so they will be traveling the same distance per unit time. However, we have already established that the projectile launched at 10° will be in the air for a longer period of time. Therefore, even if both projectiles travel horizontally at, for example, 10 m/s, the one that stays in the air longer will have traveled furthest when it hits the ground.

Q 66 B PHY 2.6, 5.3/4

You should be familiar with the equations for kinetic energy ($E_k = ½ mv^2$) and potential energy ($E_p = mgh$). In projectile questions, the height at which the projectile is launched is typically considered to be zero, and therefore the projectile has no potential energy initially. As the projectile gains height, its potential energy increases. This occurs as the projectile converts its initial kinetic energy into gravitational potential energy until it reaches maximum height (and for a moment, has no kinetic energy). The projectile then descends again (decreasing in height), thereby converting its E_p back into E_k until it reaches the ground. This information leaves us with answer choices **B.** and **C.** Answer choice **C.** can quickly be discarded, however, because it suggests that after all the projectile's kinetic energy is converted into potential energy (at the maximum height of the projectile's path), the potential energy is then converted into heat (and thereby lost). This cannot be true since the potential energy must be converted back into the kinetic energy of the projectile as it descends. Answer choice **B.** is correct.

Q 67 B PHY 1.1

This question can be answered by resolving the velocity vector into its horizontal and vertical components (in a right triangle).



With the help of a little trigonometry (SOH-CAH-TOA; Sine = Opposite/Hypotenuse, Cosine = Adjacent/Hypotenuse, Tangent = Opposite/Hypotenuse), we can solve this problem. The hypotenuse is the resultant velocity vector of the projectile, and the angle of elevation (α) is the angle it makes with the horizontal. The equation for sine α for this triangle is:

$$\text{sine } \alpha = \text{vertical velocity / horizontal velocity}$$

and therefore,

$$\text{vertical velocity} = \text{sine } \alpha \times \text{horizontal velocity}$$

In this equation, horizontal velocity is like the proportionality constant, and therefore vertical velocity is directly proportional to sine α (sine of the angle of elevation). None of the other equations (cosine α, tangent α), or α itself, are directly proportional to the vertical velocity.

<u>Q 68</u> A PHY 5.3

In the absence of air resistance, horizontal speed does not change (and thus does not have maximum and minimum values) and so we can eliminate answer choices **B.** and **D.** As explained in Q66, the E_k of the projectile will be converted to E_p until it reaches its maximum height. At this point E_k is minimal, and so the vertical velocity must also be at its minimum because $E_k = ½\ mv^2$.

<u>Q 69</u> D P2, L4-7

This question is the opposite of Q65. The same vertical speed means that both projectiles spend an equal amount of time in the air, eliminating answer choices **A.** and **B.** The projectile with the higher horizontal speed will travel a farther distance in the same amount of time as the projectile with the lower horizontal speed, making answer choice **D.** correct.

<u>Q 70</u> A PHY 2.4; deduce

At higher altitudes, the projectile will experience a decrease in air resistance as a result of the lower density of air. In addition, from the equation describing the gravitational force, $F = K_G m_1 m_2/r^2$ (*see* Q57), we see that a higher altitude (high r) will result in a decrease of this force.

<u>Q 71</u> C PHY 5.3

At maximum height, the initial kinetic energy ($E_k = ½\ mv^2$) of the projectile will be completely converted into potential energy ($E_p = mgh$) and the velocity of the projectile will be zero. To answer this question, we calculate the initial vertical kinetic energy of the projectile:

$$E_k = ½\ mv^2$$

$$\rightarrow E_k = ½ \times 5 \times 50^2 \rightarrow E_k = 2.5 \times 2500 \rightarrow E_k = 6250\ \text{J}$$

Then equate it to potential energy, because at maximum height all of the kinetic energy will be converted to potential energy:

$$E_p = mgh$$

$$\rightarrow mgh = 6250 \rightarrow h = 6250/mg \rightarrow h = 6250/5 \times 10$$
$$\rightarrow h = 6250/50$$

$$\therefore h = 125 \text{ m.}$$

This question can also be solved by using the formula $v = v_o + at$, where $v = 0$ at maximum height, and $a = g$. From this, we calculate the time it takes to reach maximum height and plug that value into the distance equation $d = v_o t + ½ at^2$.

Q 72 C PHY 2.5

The air resistance is caused by air molecules striking the projectile. As the speed of the projectile increases, the number of molecules striking the projectile will also increase. The air resistance causes a drag force on the projectile that is dependent on shape, size and velocity of the object. Therefore, as the speed of the projectile increases, the drag force increases.

Q 73 B PHY 6.1.4

Viscosity is the resistance to flow of layers of fluid as they move past one another in streamline or laminar flow. The layers of fluid in a highly viscous substance do not move easily past one another and thereby resist flow (think molasses). It may seem odd, because we are used to thinking of friction between solid objects, but this phenomenon demonstrates friction between layers of fluid. By increasing the pressure differential, the force on the liquid will increase (since pressure = force/area) and counteract the opposing frictional force of the viscosity to maintain the same volume flow rate.

Q 74 B PHY 10.1

Current is defined as the amount of charge flowing past a point in a given amount of time. This is analogous to the volume flow rate, which is the amount of fluid flowing past a point per second.

Q 75 A P3, L1-4; T2

In Experiment 2, the length of the pipes was varied while the radius and pressure differential remained constant. The question asks for the greatest kinetic energy *per unit* *length.* Since kinetic energy = ½ mass × velocity^2, we can take each trial's flow rate (velocity) to be proportional to the kinetic energy, and thus we can compare these values per unit length. Using $f(m^3/s)$ / L(m) for each trial, we find:

$$2.7 \times 10^{-7}/1 > 1.7 \times 10^{-7}/1.5 > 1.3 \times 10^{-7}/2 > 1.0 \times 10^{-7}/2.5 > 8.7 \times 10^{-8}/3$$

Trial 1 > Trial 2 > Trial 3 > Trial 4 > Trial 5

You don't need to actually perform these calculations to figure this out. With each progressive trial, the numerator of the equation, f, gets smaller, while the denominator, L, gets larger. This necessitates that with each progressive trial, the flow (kinetic energy) per unit length decreases.

<u>Q 76</u> D P1, L8; P2, L5-6

Experiment 1 was carried out by holding flow rate (f) and length (L) constant and varying radius (r) while measuring the pressure differential (ΔP). We can answer this question in two different ways: (1) simply substituting the known values into Poiseuille's equation and solving for ΔP, or (2) replacing the values that do not change with a constant, solving for that constant using the experimental data, and then substituting the given radius value.

(1) Using Poiseuille's equation ($\Delta P = 8\eta Lf/\pi r^4$) with L = 5 and f = 0.003 (as in all other trials), $\eta = 1 \times 10^{-3}$ (P2, L5-6) and r = 0.06 (given in the question):

$$\Delta P = (8 \times 1 \times 10^{-3} \times 5 \times 0.003)/(3 \times (0.06)^4)$$
$$\rightarrow \Delta P = (8 \times 1 \times 10^{-3} \times 5 \times 3 \times 10^{-3})/(3 \times (6 \times 10^{-2})^4)$$
$$\rightarrow \Delta P = (120 \times 10^{-3} \times 10^{-3})/(3 \times 6^4 \times 10^{-8})$$
$$\rightarrow \Delta P = (12 \times 10^{-2} \times 10^{-3})/(3 \times 36^2 \times 10^{-8}) \rightarrow \Delta P = (12 \times 10^{-2}/3 \times 36^2) \times 10^5$$
$$\rightarrow \Delta P = (12 \times (1/10)^2/3 \times 36^2) \times 10^5 \rightarrow \Delta P = [4 \times 1/(36^2 \times 10^2)] \times 10^5$$
$$\rightarrow \Delta P = 4 \times 10^5/36^2 \times 10^2 \rightarrow \Delta P = 4 \times 10^3/36^2 \rightarrow \Delta P = 4 \times 10^3/4^2 \times 9^2$$
$$\rightarrow \Delta P = 4^{-1} \times 10^3/10^2 \rightarrow \Delta P = \tfrac{1}{4} \times 10^1 \rightarrow \Delta P = 10/4$$

$$\therefore \Delta P = 2.5 \text{ (approximately)}$$

This calculation is quite long. It may be easier to use the next method.

(2) We know that $8\eta Lf/\pi$ will always be the same for this experiment, so we can set up the equation with this part as a constant:

$$\Delta P = \text{constant}/r^4$$

Picking any trial (in this case we will use Trial 1) and substituting the values for ΔP and r into the equation, we can solve for the constant:

$$\text{constant} = \Delta P \times r^4 \rightarrow \text{constant} = (6.0) \times (5 \times 10^{-2})^4$$

To calculate ΔP for the additional trial, we use the same equation (ΔP = constant/r^4), using the value for the constant determined above, and using $r = 6 \times 10^{-2}$:

$$\Delta P = \text{constant}/r^4 \rightarrow \Delta P = (6.0) \times (5 \times 10^{-2})^4/ (6 \times 10^{-2})^4$$
$$\rightarrow \Delta P = 6 \times 5^4 \times 10^{-8}/(6^4 \times 10^{-8}) \rightarrow \Delta P = 6 \times 25^2/36^2 \times 10^{-8}/10^{-8}$$
$$\rightarrow \Delta P = 6 \times 25^2/36^2 \rightarrow \Delta P = 6 \times (25/36)^2 \rightarrow \Delta P = 6 \times (24/36)^2$$
$$\rightarrow \Delta P = 6 \times (2/3)^2 \rightarrow \Delta P = 6 \times 2^2/3^2 \rightarrow \Delta P = 6 \times 4/9 \rightarrow \Delta P = 24/9$$
$$\rightarrow \rightarrow \Delta P = 2 + 6/9 \rightarrow \Delta P = 2 + 2/3$$

$$\therefore \Delta P = 2.67$$

Therefore, answer choice **D.** is correct.

<u>Q 77</u> A P1, L8; P2, L5-6; P3, L5

When you solve for flow rate in Poiseuille's equation ($f = \Delta P \pi r^4/8\eta L$), density is not even a factor involved, and so answer choices **A.** and **D.** can be eliminated right away. Upon inspection of Poiseuille's equation, $\Delta P = 8\eta L f/\pi r^4$, we see that with all else being constant, the flow rate will increase with decreasing viscosity ($f = \Delta P \pi r^4/8\eta L$). This makes sense because highly viscous fluids resist flow. Therefore, since the viscosity of water is lower than that of glycerin (P2, L5-6; P3, L5), it will flow faster in the pipes.

<u>Q 78</u> C P1, L8

For this question, every variable in Poiseuille's equation ($\Delta P = 8\eta L f/\pi r^4$) is constant except for f/r^4. To get the percentage by which f decreases when r decreases by 33%, set up a ratio where r_1 and f_1 are the initial radius and flow rate, respectively, and r_2 and f_2 are the radius and flow rate after the radius has been decreased by 33%.

$$f_1/r_1^4 = f_2/r_2^4$$

Since $r_2 = 2/3r_1$ (it is decreased by 1/3, therefore there is 2/3 left), we can substitute this into the equation and solve for f_2:

$$f_1/r_1^4 = f_2/(2/3r_1)^4 \rightarrow f_1/f_2 = r_1^4/(2/3)^4 r_1^4 \rightarrow f_1/f_2 = 1/(16/81)$$
$$\rightarrow f_1/f_2 = 81/16 \rightarrow f_1/f_2 = 5 \text{ (approximately)} \rightarrow f_2 = f_1/5$$

$$\therefore f_2 \text{ is equal to } 1/5 \text{ (or 20\%) of } f_1$$

If f_2 is equal to 20% of f_1, then f_1 must decrease by 80% to become f_2, and thus answer choice **C.** is correct.

Q 79 C P1, L8; P3, L5; T2

This question is basically asking you to repeat what you did for Q76. In this case, the radius and pressure differential are held constant and the length of the pipe is varied while measuring the flow rate. Using Poiseuille's equation ($\Delta P = 8\eta Lf/\pi r^4$), with $\Delta P = 100$ and $r = 0.01$ (as in all trials), $\eta = 1.5$ (P3, L5) and $L = 4$ (given in question), we have:

$$\boxed{\Delta P = 8\eta Lf/\pi r^4}$$

$$\rightarrow f = \Delta P\pi r^4/8\eta L \rightarrow f = 100 \times 3 \times 0.01^4/8 \times 1.5 \times 4$$
$$\rightarrow f = 300 \times (1 \times 10^{-2})^4/12 \times 4 \rightarrow f = 300 \times 10^{-8}/48 \rightarrow f = 300 \times 10^{-8}/50$$

$$\therefore f = 6 \times 10^{-8} \text{ (approximately)}$$

Alternatively, we know that $\Delta P\pi r^4/8\eta$ will always be the same for these experiments, and so we can set up the equation with this part as a constant. Then we can plug in values from any trial (we will use Trial 1) to solve for the constant:

$$f = \text{constant}/L \rightarrow \text{constant} = (L)(f)$$
$$\rightarrow \text{constant} = (1)(2.6 \times 10^{-7})$$

Then, using L = 4m (given in the question):

$$f = \text{constant}/L \rightarrow f = (2.6 \times 10^{-7})/4 \rightarrow f = 26 \times 10^{-8}/4 \times 10^0$$

$$\therefore f = 6.5 \times 10^{-8}.$$

Therefore, answer choice **C.** is correct.

Q 80 A P1, L8; Ap A.3

We know from Poiseuille's equation, $\Delta P = 8\eta Lf/\pi r^4$, that the pressure differential (ΔP) is directly proportional to the volume flow rate (f) of the fluid. When f increases, so does ΔP. Only answer choice **A.** represents a graph with this type of linear relationship (y = x). Answer choice **D.** represents an direct inverse relationship, which suggests that when f increases, ΔP decreases. Answer choices **A.** and **B.** do not depict a direct linear relationship between f and ΔP, and thus are incorrect.

Q 81 D PHY 1.1, 4.3, 5.3/4

If there is no air resistance, the only force acting on the ball is gravity. A projectile has a vertical and horizontal component of velocity. Since gravity will affect the only the vertical velocity of the ball, the horizontal velocity will remain unchanged between the first and second impacts. The vertical speed changes throughout the motion, and so the overall momentum ($M = mv$) and kinetic energy ($E_k = \frac{1}{2} mv^2$) of the ball will change. The potential energy ($E_p = mgh$) changes as the height of the ball increases and decreases.

Q 82 C P2, L4-5

This is an easy question. The timer "measures the time (t) between the 2 impacts."

Q 83 C T1; deduce

This question can be answered by comparing the time values for the different balls in Table 1. Balls C and D failed the test, while Balls A and B passed. The time of Ball C is lower than the times of both Ball A and B. The time of Ball D is higher than both Ball A and B. This means that somewhere between the times of 0.97 s and 1.09 s lies the range of times which correspond to acceptable heights as determined by the equation given in the passage ($h = gt^2/8$). However, we do not know the exact cutoff numbers. The only thing we can be certain of is that the range of times between the times of Ball A and Ball B (1.01-1.05 s) must represent a range of times that correspond to heights acceptable for passing the test. Only the time in answer choice **C.** fits into this range and therefore is the only one that we can say will *definitely* pass the test.

Q 84 B P2, L6

To calculate the percentage of original potential energy (E_p) lost, we need to find how much potential energy the ball had initially (just before being dropped). Using the equation for potential energy ($E_p = mgh$) with h = 2m:

$$\boxed{E_{p(o)} = mgh}$$

$$\rightarrow E_{p(o)} = 2mg$$

where $E_{p(o)}$ is the initial potential energy.

Now we need to know how much potential energy the ball had at its maximum rebound height. To do this, we need to know what the maximum rebound height was. The passage gives an equation for this value, which we can substitute into the potential energy equation:

$$E_{p(h=max)} = mg(gt^2/8)$$

where $E_{p(h=max)}$ is the potential energy at the maximum rebound height.

Now we can set up the ratio $E_{p(h=max)}/E_{p(o)}$ to find the percentage of $E_{p(o)}$ present in $E_{p(h=max)}$:

$$E_{p(h=max)}/E_{p(o)} \rightarrow mg(gt^2/8)/mg(2) \rightarrow gt^2/8 \times 2$$

$$\rightarrow gt^2/16$$

Substituting in our values for g and t, we have:

$$10 \times 0.97^2/16 \rightarrow 10 \times 1/16 \rightarrow 10/16$$

$$\therefore 0.6 \text{ or } 60\% \text{ (approximately)}$$

Therefore, if $E_{p(h=max)} = 60\%$ of $E_{p(o)}$, then at maximum height, the ball has lost (100-60%) 40 % of its original potential energy, making answer choice **B.** correct.

<u>Q 85</u> B PHY 1.5, 5.3/4

There are two ways to answer this question:

(1) using the equation $x = x_o\ v_ot + \frac{1}{2}\ gt^2$, solving for t and plugging that value into the equation v = at, or

(2) since the potential energy(E_p) of the ball at the height of 2m will be completely transformed into kinetic energy (E_k) once the ball hits the ground (according to the conservation of energy of an isolated system), we can equate E_p (mgh) to E_k ($\frac{1}{2}\ mv^2$) and solve for velocity.

Since method (1) will involve a square root (and no calculators allowed!), it's probably better to go with method (2), as follows:

$$E_p = E_k \rightarrow mgh = \tfrac{1}{2}\ mv^2 \rightarrow gh = \tfrac{1}{2}\ v^2 \rightarrow v^2 = 2gh \rightarrow v = (2gh)^{1/2}$$
$$\rightarrow v = (2 \times 10 \times 2)^{1/2} \rightarrow v = 40^{1/2} \rightarrow v = 4^{1/2} \times 10^{1/2} \rightarrow v = 2 \times 10^{1/2}$$
$$\rightarrow v = 2 \times 9^{1/2} \rightarrow v = 2 \times 3$$

$$\therefore v = 6 \text{ m/s (approximately)}$$

Therefore, answer choice **B.** is correct.

Q 86 D **P5, L5; L9**

To answer this question, we look at the 2 equations involving k: (1) $f = 1/(2\pi)\ (k/I)^{1/2}$, where $I = 1/12\ M(\text{width}^2 + \text{length}^2)$, and (2) $k = \mu\beta$. From the dimensions and the mass of the magnet, we can calculate I, leaving f and k as the only unknowns in equation (1). Therefore, if we know f, and we also know the dimensions and mass of the magnet, we can solve the equation $f = 1/(2\pi)\ (k/I)^{1/2}$ for k.

Q 87 B **P5, L3-5**

The passage indicates that the simple harmonic motion occurs because the restoring force is equal to the angle when the angle is small.

Q 88 B **P5, L9**

Using the equation $k = \mu\beta$, the value of the Earth's magnetic field (β) can be calculated by knowing k and μ. If k is known, as the question states, then we need to know only μ to solve the equation for β.

Q 89 A **P4, L2; P5, L11**

Rearranging the equation $I = 1/12\ M\ (\text{width}^2 + \text{length}^2)$, where I = moment of inertia and M = mass of the magnet, we have:

$$I = 1/12\ M\ (\text{width}^2 + \text{length}^2) \rightarrow M = 12 \times I/(\text{width}^2 + \text{length}^2).$$

Substituting in the known values of width, length (P4, L2) and I (given in question), we have:

$$M = 12\ (1.4 \times 10^{-3})/(0.02^2 + 0.20^2) \rightarrow M = (12)(1.4)(10^{-3})/(0.0004 + 0.04)$$
$$\rightarrow M = (12)(1.4)(10^{-3})/(0.0404) \rightarrow M = (12)(1.4)(10^{-3})/(4 \times 10^{-2})$$
$$\rightarrow M = (12/4)(1.4)(10^{-3}/10^{-2}) \rightarrow M = 3 \times 1.4 \times 10^{-1} \rightarrow M = 3 \times 0.14$$
$$\rightarrow M = 0.42 \text{ kg (approximately).}$$

Therefore, answer choice **A.** is correct.

Q 90 C **P2, L3; P4, L5**

Using the equation $\tau = \mu\beta \sin\theta$, where θ is the angle the magnet makes with the magnetic field, μ is the magnetic dipole moment of the magnet and β is the magnetic field strength, we get:

$$\boxed{\tau = \mu\beta \sin\theta}$$

$$\rightarrow \tau = (1.5 \times 10^3)(0.01) \sin 90° \rightarrow \tau = 1.5 \times 10^3 \times 10^{-2} \times 1$$
$$\therefore \tau = 1.5 \times 10^1 \text{ N m.}$$

Therefore answer choice **C.** is correct.

<u>Q 91</u> C **deduce**

The Earth is like a big magnet where the magnetic north pole points towards the geographic south pole and the magnetic south pole points towards the geographic north pole. The magnetic field lines around the Earth start at one pole and curve toward the other, following the shape of the Earth. Midway between the poles the lines are parallel to the vertical axis of the earth. To align with the magnetic field while being held at either pole, the magnet has to move in the vertical plane. However, while being held midway between the poles, the magnet can align parallel to the field lines without motion in the vertical plane.

It is important to visualize this situation properly. A person standing on the Earth at the North Pole would essentially be at a right angle to a person standing on the Earth at the midpoint between the poles (the equator). Thus, the magnets that they hold will have differing horizontal and vertical planes. Taking the horizontal planes of the magnets to be in the direction of the length of the magnet, you should be able to see that the magnet at the North Pole will have to move outside of its horizontal plane to align with the magnetic field lines (which run North to South), while a magnet at the midpoint will not have to do this.

<u>Q 92</u> C **PHY 4.1**

Recall that torque (τ) is the turning force multiplied by the perpendicular distance from a pivot point, which in this case is where the silk fiber is attached at the center of mass. When a magnetic field is applied at 90° to the magnet, the magnet will feel two forces (F) in opposite directions (because the opposite poles will align in opposite directions) which work together to align the magnet. These forces are additive. We can calculate the total torque by adding the torques of F_1 and F_2.. The magnet is 0.20m long and is suspended by its center of mass, so each force is acting at a distance (d) of 0.10m from the pivot point. Letting F_1 and F_2 be the forces acting at either end of the magnet, and d_1 and d_2 be the distance from the pivot point of each force, we have:

$$\tau = F_1d_1 + F_2d_2 \rightarrow \tau = (1)(0.10) + (1)(0.10)$$

$$\therefore \tau = 0.2 \text{ N.}$$

Therefore, answer choice **C.** is correct.

Q 93 A P5, L5; L11

By looking at our equation for frequency, $f = 1/(2\pi)\ (k/I)^{1/2}$, where $I = 1/12\ M(\text{width}^2 + \text{length}^2)$, we see that the only variable which will cause f to increase is k.

Q 94 D P5

If the silk fiber is attached slightly off center, the magnet will not be perfectly horizontal, violating the condition of the equation for I. If I is then calculated incorrectly, it will lead to an inaccurate value of f when used in that equation. Answer choices **A.** and **B.** will help the accuracy of the experiment since an increase in trials (oscillations) will result in a more accurate calculation of the period and a smaller angle will better approximate the model of simple harmonic motion. Note that changing to a plastic fiber should not affect the results because the corresponding change in the value of k is factored into our equations.

Q 95 C P2, L1-2

The passage indicates that a buffer requires an acidic and a basic species which will react with added OH^- and H^+, respectively. Therefore, if these 2 species consume each other through a neutralization reaction (e.g. $NaOH + HCl \rightarrow NaCl + H_2O$), they will not be available to react with added ions and this will no longer be a buffering solution.

Q 96 D P2, L1-2; Equation; CHM 9.9

The small quantity of base will react with the acidic species of the buffer, in this case is the H^+, to keep the pH of the solution relatively unchanged. According to Le Chatelier's Principle, if the species on the right of the equation is consumed, the equilibrium will shift to the right.

Q 97 A deduce

Looking at the Henderson-Hasselbach equation given in the passage, $pH = pK_a + \log [\text{base}]/[\text{acid}]$, we can see what the effects of varying the [base]/[acid] ratio are. Recall that log 1 = 0, and that the log of anything less than 1 is a negative number. We want the "log [base]/[acid]" part of the equation to be positive in order to add to the pK_a and thereby increase the pH, and so we want the [base]/[acid] ratio to be greater than 1.

Increasing the ratio of [base]/[acid] ensures that the value of log [base]/[acid] is greater than 1, and thus increases the pH.

Q 98 B **deduce**

Remember that the *p* of something (i.e. pK_a) means "the negative log of..." We can take the Henderson-Hasselbach equation and substitute all the "p"s with "-log" to get:

$$pH = pK_a + \log [base]/[acid]$$

$$\rightarrow -\log [H^+] = -\log K_a + \log [base]/[acid]$$

To get answer choice **B.**, multiply the equation by -1.

Q 99 D **P1, L4-6**

The buffering capacity of a solution is equal to the amount of acidic or basic species neutralized before the pH begins to change substantially. Therefore, the more acidic and basic species available to neutralize added ions, the better the buffer.

Q 100 A **deduce**

A dilution of the solution will lead to lower concentrations of base and acid, however, the ratio of [base]/[acid] will remain unchanged because both species are diluted the same amount. If this value is unchanged in the equation pH = pKa + log [base]/[acid], then the pH remains the same.

Q 101 B **CHM 5.2, 5.3.2**

Any solute that dissolves in water to produce ions that conduct electricity is considered an electrolyte. Strong electrolytes dissociate extensively in aqueous solutions (as shown by one arrow in the reaction $NaCl \rightarrow Na^+ + Cl^-$) while weak electrolytes dissociate incompletely (as shown by 2 half arrows pointing in opposing directions in the equation). In this case, $HC_2H_3O_2$ is a weak electrolyte because the reaction is reversible (as shown by the two half arrows). In general, salts such as $NaC_2H_3O_2$ are considered strong electrolytes.

Q 102 D **P2, L3-5**

A buffered mixture consists of an acid-base conjugate pair made by mixing a weak acid or base with its salt. In this case, ammonia (NH_3) is the weak base and we must chose its salt from the answer choices. The salt must contain the conjugate acid of ammonia (NH_4^+), thus eliminating answer choices **A.** and **B.** Answer choice **C.** is incorrect because the base OH^-, which will be released upon dissociation, does not act as a spectator ion and thus will adversely affect the buffering capacity of the solution.

Q 103 C deduce

If the concentrations of acid and base are equal, then the ratio [base]/[acid] in the Henderson-Hasselbalch equation will be equal to 1, and we will have:

$$pH = pK_a + \log [base]/[acid]$$

$$\rightarrow pH = pK_a + \log 1 \rightarrow pH = pK_a$$

Note that the maximum buffering capacity of any buffer occurs when this condition is met.

Q 104 A P4

Chemist 2's theory is that speed will determine the pathway followed by one substance when presented with two possible reactions. The product of the fastest reaction is the most likely to form. However, the product of the slower reaction may form as well, just not in as large amounts as the faster-produced product. This theory implies that if two pathways have the same rate, the products of the reactions should form in equal proportions.

Q 105 D deduce

C_2H_4 and CH_3CHO are *products* of the decomposition of ethanol. Therefore, the initial concentrations (at time = 0) of these molecules should be zero, eliminating the graphs in answer choices **A.** and **B.** If C_2H_4 is being formed at twice the rate of CH_3CHO then there should be twice as many C_2H_4 molecules at the end of the reaction, as shown by answer choice **D.**

Q 106 C CHM 9.5

As a rule, the rate of a reaction will increase with increasing temperature because a rise in temperature increases the kinetic energy of the molecules, which brings them closer to overcoming the activation energy of the reaction. If the rate of our reaction does not increase as a result of increasing temperature, then the kinetic theory of Chemist 2 is most challenged, since product should form at a faster rate under these conditions.

Q 107 D **deduce**

The product ratio means the ratio of products formed from pathway 1 and pathway 2 (i.e. the ratio of C_2H_4 to CH_3CHO). Both chemists have clear ideas about which conditions cause which pathways to be followed. In order for them to have faith in their ideas, they would have to agree that a certain product ratio can be reproduced by implementing exactly the same conditions. Although they may disagree on what the particular conditions are, they have to agree that the conditions act on the product ration in the same way each time they are present.

Q 108 A **P3, L5-6**

Chemist 1 believes that the more exothermic reaction pathway will be favored. Therefore, if Path 2 were the only one observed, Chemist 1 would likely say that this pathway is more exothermic than the alternative path.

Q 109 B **P3, L7-8**

Chemist 1's theory is flawed since it indicates that endothermic reactions (where the bond strength of the reactants exceeds that of the products) are forbidden. However, endothermic reactions are known to occur, and Chemist 1's theory does not allow for this.

Q 110 C **P3, L4-6**

Answer choices **A.** and **D.** can be eliminated since they talk about energies of activation and rates of reaction, which are two components of the kinetic theory of Chemist 2. Chemist 1 argues that the species with the stronger, most stable bonds will be formed preferentially. By comparing the total bond energies of the 2 sets of products, we can determine which is the most likely to form. Answer choice **C.** is incorrect because the bonds being compared are both in the reactant, ethanol.

Q 111 C **CHM 9.8**

In a reversible reaction, both forward and backward reactions are occurring at variable rates. Equilibrium is reached when the forward reaction rate equals the backward reaction rate such that the overall concentrations of reactants and products remain unchanged despite the fact that molecules continue to follow both reaction pathways.

Q 112 B   P1, L8;CHM 9.8

The equilibrium *constant* (K_{eq}) of a reaction is affected by temperature but not by molar concentrations of the species in the reaction. The passage gives the value of K_{eq} at 25°C, and this value is not changed by adjusting the molar ratio of reactants.

Q 113 A   CHM 9.8

Recall that K_{eq} = [products]/[reactants]. If K_{eq} is increased, then the relative ratio of [products]/[reactants] increases, resulting in a larger yield of product for the reaction.

Q 114 B   CHM 1.6

Oxidation involves the gain of oxygen or the loss of hydrogen. Answer choice **D.** can be eliminated since in this example, ethanol has undergone a dehydration reaction. Answer choice **C.** contains too many carbons. The question is asking what the *first* step in the oxidation of an alcohol would be. By looking at the leftover choices, the most likely reaction mechanism is that ethanol is *first* oxidized to an aldehyde (answer choice **B.**) by losing a hydrogen, and then to a carboxylic acid (answer choice **A.**) by gaining an oxygen.

Q 115 A   P1, L2-3

The passage indicates that one reason reactions involving organic compounds are low-yielding is the low value of the equilibrium constant. Since K_{eq} represents the relative [products]/[reactants] ratio when the reaction has reached equilibrium, a low K_{eq} value means that the product concentration is low at equilibrium and the reaction has not gone to completion.

Note that completion means that the reactants have all been converted to products and K_{eq} has a value approaching zero.

Q 116 D   CHM 9.8

The equilibrium constant (K_{eq}) represents a thermodynamic property of the system, which is affected by the relative energies or stability of the products and reactants. A change in concentration of the reactants or the molar ratios will have no effect on stability, but will increase the rate (a kinetic property) of the reaction. The addition of a catalyst will increase the rate by lowering the activation energy, however, the relative stability of the molecules will remain the same. Temperature will increase the kinetic energy of the molecules, bringing reactants closer to the energy of activation, causing a shift in equilibrium to the right and increasing K_{eq}.

<u>Q 117</u> C CHM 6.1; T1

You should know the relative strengths of bases and acids (i.e. which are strong, which are weak). Answer choice **B.** can be eliminated because all trials involve monoprotic acids but have a range of ΔT's. Similarly, the base NaOH in Trial 3 yields a reaction with a different ΔT than Trials 1 and 5, eliminating answer choice **D.** The close values of ΔT are a result of the similar nature of the reacting species, which lead to similar reactions. HCl and HNO_3 are both strong acids reacting with the strong base NaOH.

<u>Q 118</u> A P1

You should know that the purpose of the styrofoam cups is to insulate the system (e.g. prevent heat from escaping). Therefore, the second cup increases the insulating power. If only one cup was used, more heat would be able to escape, and thus the observed rise in temperature of the liquid would be less (less heat available to warm the liquid).

<u>Q 119</u> D deduce

You should know that heat is not normally supplied by stirring. Also, the neutralization reactions are spontaneous, and so they do not require an input of heat for initiation. It is reasonable that the stirrer is used to mix the solution and to avoid temperature gradients, which would in turn help reduce experimental error in measuring the temperature.

<u>Q 120</u> C T1; CHM 6.1

The least exothermic reaction is the one with the lowest ΔT in Table 1 (i.e. the one that releases the least heat). Trial 6, the least exothermic reaction, involves the reaction of the strong acid HNO_3 and the weak base NH_3. As in Q117, you need to know which acids and bases are strong and which are weak.

<u>Q 121</u> D P2, L2-4

A neutralization reaction between a strong acid (HCl) and a strong base (NaOH) essentially goes to completion. Therefore, we can assume that the following reaction went to completion:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The initial number of moles of acid or base is equal to the concentration of acid or base multiplied by the volume of acid or base, therefore:

$$2 \text{ moles/L} \times 0.05 \text{ L} = 0.10 \text{ moles}$$

Since the stochiometric ratio of reactants to products is 1:1, 0.10 moles of acid reacting with 0.10 moles of base will form 0.10 moles of NaCl.

Q 122 D deduce

The main difference between bombs and coffee-cup calorimeters is that bombs are sealed. Therefore, it is likely that this extra feature is required to prevent the escape of gaseous products, which would be released to the surroundings if the reaction takes place in a coffee-cup calorimeter.

Q 123 B CHM 8.10; T1

In addition to the equation in the passage, the Gibbs free energy (G), can be calculated in two ways: (1) $\Delta G = \Delta H - T\Delta S$, where H = enthalpy, T = temperature and S = entropy, and (2) $\Delta G_{reaction} = \Sigma G_{f(products)} - \Sigma\Delta G_{f(reactants)}$, where ΔG_f = free energy of formation. In this example, the ΔG_f's for both reactants and products are given in Table 1. For equation (2), recall that the ΔG_f of elements is 0 and that the number of moles of each species must be factored into the equation. Plugging in the values from Table 1 into equation (2) we get:

$$\Delta G^\circ_{rxn} = \Sigma G^\circ_{f(products)} - \Sigma\Delta G^\circ_{f(reactants)}$$

$$\rightarrow \Delta G^\circ_{rxn} = (2 \text{ moles } NO_2 \times 51.84 \text{ KJ/mole}) - (2 \text{ moles NO} \times 86.69 \text{ KJ/mole} + 0)$$

$$\rightarrow \Delta G^\circ_{rxn} = (2 \times 50) - (2 \times 85) \rightarrow \Delta G^\circ_{rxn} = 100 - 170$$

$$\therefore \Delta G^\circ_{rxn} = -70 \text{ KJ (approx.)}.$$

Therefore, answer choice **B.** is correct.

Q 124 D P3; CHM 9.8

In this example, the higher ratio of products to reactants will result in a positive K since K = [products]/[reactants]. In fact, from this definition of K we can see that K can never be negative (you can't have negative concentrations), and so answer choices **B.** and **C.** are eliminated. By looking at the equation $\Delta G^\circ_{rxn} = -2.3 \text{ RT} \log K$, you can see that RT will always yield a positive number (R is positive constant and absolute temperature is never negative). Knowing that K is also positive means that the -2.3 makes ΔG°_{rxn} negative.

<u>Q 125</u> C deduce

Reactions occur either at standard state, (indicated by °), or under non-standard (other) conditions. To find ΔG *at standard state* ($\Delta G°$) using the equation given, all variables involved must be taken at standard state. Since F is a constant, and n is the number of moles, E is the only variable that we must be sure is measured at standard state. That is why the passage gives the equation $\Delta G° = -nFE°$, in which both ΔG and E are at standard state. We are looking for an equation that is consistent with this one ($\Delta G° = -nFE°$). There is a negative on the right side of the equation, eliminating answer choices **A.** and **B.** Answer choice **D.** gives an almost identical equation, except only one of ΔG and E are at standard state. This is not consistent with the equation in the passage, and does not make sense because if we are not trying to find ΔG at standard state ($\Delta G°$), we do not need to use E at standard state (E°). Only Answer choice **C.** is consistent with the equation in the passage since *both* G and E are not at standard state.

<u>Q 126</u> A T1; CHM 8.10

In order for a reaction to be spontaneous (or favorable), $\Delta G_{rxn} < 0$. The free energies ($\Delta G°$) of coupled reactions are additive and can be used to obtain the overall $\Delta G°_{rxn}$:

$$\Delta G°_{rxn} = \Delta G°_{rxn\#1} + \Delta G°_{rxn\#2}$$

Substituting the $\Delta G°$ for ATP formation into $\Delta G°_{rxn\#1}$, we have:

$$\Delta G°_{rxn} = 7.6 \text{ kJ} + \Delta G°_{rxn2}$$

In order for the coupled reaction to be favorable, we must find a reaction whose $\Delta G°$ is such that when added to 7.6 the sum is less than zero. Only Reaction 1 will do this:

$$\Delta G°_{rxn} = 7.6 + (-14.7) \rightarrow \Delta G°_{rxn} < 0.$$

Therefore, answer choice **A.** is correct.

<u>Q 127</u> C Ap A.4.2; deduce

We need to look at an equation involving both $\Delta G°$ and K to find the relationship between them. Look at the equation $\Delta G°_{rxn} = -2.3 \text{ RT} \log K$. We can regard 2.3RT as a constant, and so $\Delta G°_{rxn}$ is proportional to the negative log of K. You should know what a log graph looks like, but you can also figure this out by reasoning that answer choice **C.** must be correct since it is the only one which represents decreasing values of $\Delta G°_{rxn}$ with increasing values of K (what you would expect if $\Delta G°$ is proportional to the negative log of K).

Q 128 A T1

The only information given for Reaction 6 is K = 1. Plugging this in to the equation $\Delta G°_{rxn} = -2.3RT \log K$, we get:

$$\Delta G°_{rxn} = -2.3 \text{ RT} \log K \rightarrow \Delta G°_{rxn} = -2.3 \text{ RT} \log 1$$

$$\therefore \Delta G°_{rxn} = 0.$$

Therefore, answer choice **A.** is correct.

Q 129 C CHM 8.10

Remember that for a reaction to be spontaneous, ΔG must be less than zero. In the equation $\Delta G° = -nFE°$, the number of moles (n) and the Faraday constant (F) are always positive. Therefore, E° is the variable that will determine whether $\Delta G°$ ends up being a negative or positive number. In order for $\Delta G°$ to be less than zero (e.g. negative), E° must be positive.

Q 130 A P1, L1-3; P3 (graph)

Graham's Law states that the rate of effusion is inversely proportional to the square root of the molecular weight. Therefore, lighter gases have a faster rate of effusion than heavier gases. The rate of the drop in pressure measured by gauge 2 corresponds to the rate of effusion. According to the graph, Gas A's rate of effusion (e.g. pressure drop) is faster than O_2 (somewhat heavy) but slower than H_2 (very light). Therefore, Gas A's molecular weight must be larger than that of H_2 but smaller than that of O_2. Only CH_4 fits these criteria.

Q 131 D P1, L1-3

The mixture of gases will have a rate of effusion in between that of the gases in pure form because both types of molecules are present and each have their own rate of effusion. Since CH_4 has a lower molecular weight than H_2S, the rate of effusion of CH_4 will be higher than the rate for H_2S. To have a rate in between these two rates, the mixture of the two gases will have a rate of effusion greater than H_2S (the slower one) but lower than CH_4 (the faster one).

Q 132 B deduce

The passage describes Graham's Law, which states that E is proportional to $(MW)^{-1/2}$. Therefore, $E_1 \alpha MW_1^{-1/2}$ and $E_2 \alpha MW_2^{-1/2}$. The ratio of E_1/E_2 will be proportional to $(MW1)^{-1/2}/(MW2)^{-1/2}$, which can be simplified to equal $(MW2)^{1/2}/(MW1)^{1/2}$, as shown in answer choice **B.**

Q 133 C P1, L1-3

According to Graham's Law, the rate of effusion will be highest for the molecules of smaller molecular weight. Therefore, the relative rates in our sample are:

$$\text{Rate of } {}^1H_1 > \text{Rate of } {}^2H_2 > \text{Rate of } {}^3H_2$$

Therefore, molecules of ${}^1H_2$ will be leaving the bulb faster than the other two molecules. Molecules of ${}^2H_2$ will leave the bulb faster than molecules of ${}^3H_2$, and thus the abundance of ${}^3H_2$ inside the bulb will increase with respect to the other two molecules.

Q 134 B deduce

Since H is the first element on the periodic table, hydrogen gas has the lowest molecular weight of all gases and consequently, the fastest rate of effusion. The unknown gas could have an equal rate of effusion, if it was actually H_2 gas, or a slower rate if it was any other gas.

Q 135 D deduce

Comparing molecular weights (MW) of the molecules:

$$\text{MW of } H_2 < \text{MW of Ne} < \text{MW of } O_2$$

Therefore, according to Graham's Law, the relative rates of effusion will be $H_2 > Ne > O_2$, eliminating answer choices **B.** and **C.**, which show neon gas to have a slower rate than both hydrogen and oxygen. The difference in the leftover choices is the initial pressure of the neon gas. Answer choice **A.** shows neon gas with an initial pressure lower than both oxygen and hydrogen, while answer choice **D.** shows neon gas with an initial pressure intermediate between the two. Using the ideal gas law:

$$\text{Pressure} \times \text{Volume (V)} = \text{number of moles (n)} \times \text{R (constant)} \times \text{Temperature (T)}$$

We can see that pressure is proportional to the number of moles in the flask. Since the number of moles = (mass of the gas sample)/(molecular weight), we can substitute this into the equation to get:

$$\text{Pressure} = \text{mass} \times R \times T / \text{molecular weight} \times V$$

For a given volume, pressure will be inversely proportional to molecular weight. Therefore, the values of the initial pressures exerted by the gases will be inversely proportional to their relative molecular weights, with H_2>Ne>O_2. Thus answer choice **D.** is correct.

<u>Q 136</u> D P1 (table)

Answer choices **A.** and **B.** can be eliminated since volume is inversely proportional to both temperature and solubility (as volume increases, both temperature and solubility decrease). The table relates temperature and solubility; it does not demonstrate a relationship between temperature and volume of salt. We are left with answer choice **D.**, which states that solubility will change with changing temperature. You can see that this is in fact true. As temperature decreases, solubility decreases.

<u>Q 137</u> A deduce

Since the question is asking about solubility at 90 °C, we should be concentrating on the column that gives the solubilities at 100 °C because this is the closest. In this column, copper sulfate has the highest solubility and thus will likely require less water to dissolve at 90 °C.

<u>Q 138</u> D P1, L4; T1

Salt will continue to dissolve in water until the water is saturated with it. Decreasing the concentration of salt does not affect the salt's ability to dissolve (e.g. its solubility), it just means that there will be less salt available to dissolve. This eliminates answer choices **A.** and **B.** Increasing the temperature of a solution increases the capacity of the solution to dissolve the salt, allowing more salt to dissolve before the solution becomes saturated. As the temperature drops, the saturation point decreases. The salt precipitates out of solution as the salt concentration exceeds the saturation point for a solution of the now lower temperature. A lower concentration of salt means that the solution will be less saturated to begin with and the temperature will have to decrease more to reach a temperature at which the salt concentration exceeds the saturation point.

<u>Q 139</u> C deduce

When determining the solubility of a salt by experimentation, the thermal stability of a compound is relevant because many methods involve heating. Similarly, the approximate solubility of the compound is important when choosing a solvent (imagine trying to determine the solubility of steel in cold water!). The rate of crystal formation is relevant when attempting to take an accurate measurement of the temperature at which crystals begin forming. However, the shape of the crystals that precipitate are not related to the solubility of the compound and should not affect the measurements taken.

Q 140 B **deduce**

Once a solution has been mixed, the concentration is uniform so that the concentration in one drop will be the same as the concentration of the remaining solution. Therefore, losing a small amount of the sample will not change the salt concentration of the rest of the sample, and thus the measurements of solubility will be unchanged.

Q 141 D **P1, L5-6**

The table shown in the passage displays the volume of water, both initially (15 ml) and after additions. This value is very important, since the solubility is being calculated per gram of water, which can be calculated from the volume using $m = \rho v$. In the description of the procedure, the passage states that the temperature at which crystals form is recorded, and thus we know this step is important. The temperature at which the salt first dissolves is not vital to the experiment.

Q 142 C **P1, L5**

According to the equation in the passage for efficiency, $e = W/Q_H$, where W = output work and Q_H = heat put in, if the amount of heat input increases, the efficiency of the system decreases when W is constant.

Q 143 B **P1 (diagram)**

In order for the steam to move the piston, it has to be under high pressure. The opening of the intake valve allows a steady flow of steam into the chamber with the piston, creating an increase in pressure. This pressure would quickly dissipate if the exhaust valve was open because the steam would pass right through to the condenser and release the buildup of gas.

Q 144 A **P2, L1-3**

The refrigerator works by absorbing heat to change the refrigerant liquid into gas. If the heat of vaporization (the amount of heat the liquid needs to absorb to change to a gas) of this liquid is greater, more heat will be absorbed, and thus the surroundings will become cooler.

Q 145 D deduce

To go from a gas to a liquid, we need to decrease the temperature of the gas until it condenses. The addition of any type of steam will not decrease the temperature of the system, as it is likely about the same temperature as the gas we are trying to cool. Circulating water will be more efficient than stationary water at cooling the gas because the heat absorbed from the gas will be quickly dissipated, thus allowing the water to absorb more heat.

Q 146 A P1, L7-8

The passage indicates that it is impossible to convert all of the input heat (thermal energy) into work. In other words, no system is 100% efficient, and thus the amount of work can only be less than the amount of thermal energy provided.

Q 147 C P1, L2-3; P1 (diagram)

The thermal energy (heat) of the steam is converted into mechanical energy (movement) of the piston when the steam pushes the piston to the right.

Q 148 C CHM 4.1.5

This question is similar to Q145. Let's review what we know about liquids and gases. The molecules of liquids are more closely associated with one another than the molecules of gases. Therefore, gases take up more space. An increase in pressure or a decrease in volume reduces the ability of the gas to move around freely, and these changes can cause a gas to change back into a liquid. An increase in kinetic energy of the molecules of a liquid causes them to move more and get farther from each other until they escape as a gas. An increase in temperature of the gas will increase its kinetic energy, and thus it will not turn into a liquid, thereby eliminating answer choices **A.** and **B.** Decreasing the pressure gives the gas more freedom to move around, and thus this does not encourage liquid formation. To condense the gas into a liquid at a constant temperature we can decrease the volume. With less space available, a gas is forced to condense into a liquid, which takes up less space.

Q 149 B P2, L1-3

The passage indicates that the refrigerant absorbs heat from the refrigerator to change from a liquid state to a gaseous state. Remember that heat will move from an area of higher heat to an area of lower heat. The boiling point of the refrigerant must be less than the temperature that we want to keep the refrigerator at, so that the refrigerant continues to draw any heat above the desired temperature away from the refrigerator. If we want to store ice in our refrigerator, the refrigerant liquid must be able to absorb heat around the 0 °C range to ensure that the fridge is kept at that temperature, which means that its boiling point will be lower than the freezing point of water.

<u>Q 150</u> A deduce

When the door is left open, the temperature inside the refrigerator climbs and more energy is required to remove the excess heat from the refrigerator. As occurs in the steam engine, an increase in work will result in an increase in heat flowing out of the system.

<u>Q 151</u> A deduce

The amount of KOH needed to dissolve the aluminum, the amount of starting material and the solubility of the aluminum are independent of the form of aluminum present initially (a whole can versus small pieces). The increase in surface area available for the solvent will increase the rate of the reaction.

<u>Q 152</u> C deduce

The maximum theoretical yield is the maximum amount of alum expected from our starting reagents, assuming that the reaction will go to completion. The temperature of the final solution, the oxidation potential of aluminum, and the purity of alum produced will not help us determine how much alum it is theoretically possible to produce from this reaction. To calculate the theoretical yield, we need to identify the limiting reagent (e.g. the reagent which will be used up first in the reaction, causing the reaction to stop even though other reactants are still present). Knowing this will allow us to calculate the number of moles of product that can be expected to form.

<u>Q 153</u> A T1

Table 1 shows that at higher temperatures, more alum remains dissolved in solution. From this, we can deduce that the alum solution was kept hot to avoid a decrease in the solubility of the compound in solution and subsequent crystallization on the filter paper.

<u>Q 154</u> B R1

Reaction 1 shows aluminum reacting with the hydroxyl (strong base) part of the KOH molecule to form aluminate ion. If a basic substance were stored in an aluminum can, it is possible that the base could react with the inside of the can to form aluminate ions, and thus basic substances should not be stored in aluminum cans.

Q 155 C T1

Table 1 shows that solubility increases steadily with temperature. Answer choices **A.** and **B.** are incorrect because they both show solubility staying the same over a certain range of temperatures (horizontal line), which is not what we observe in the data. Answer choice **D.** shows solubility steadily decreasing over time, which is also not what we observe in the data. Answer choice **C.** accurately displays the trend shown in the table, and thus is the correct choice.

Q 156 B T1

Since solubility is proportional to temperature, a further decrease in temperature would increase the amount of alum crystallizing out of solution.

Q 157 D R1; CHM 4.1.6

Recall the ideal gas law, PV = nRT, where P = pressure, V = volume, n = # of moles, R = ideal gas constant and T = temperature. If R is unknown then this equation cannot be used to solve for n. Therefore, to calculate the number of moles of hydrogen gas, we can use Reaction 1. In describing Reaction 1, the passage states that a known amount of magnesium is reacted with acid, suggesting that it is the amount of magnesium that is important. It is reasonable that an excess amount of acid could be added in order to completely react all of the magnesium. So, since magnesium is the limiting reagent, we need to find out how many moles of magnesium we have in order to determine how many moles of hydrogen gas form. If we know the mass of magnesium, we can divide it by the molecular weight of magnesium to obtain the number of moles. This number is equal to the number of moles of hydrogen gas formed since the ratio of magnesium to hydrogen gas in the reaction is 1:1.

Q 158 A deduce

The gas produced by Reaction 1 in our experiment rises to the top of the closed buret and increases the pressure, causing the water to be pushed down to a lower level in the buret. The difference in water levels can be used to calculate the volume of gas produced. In order to carry out this experiment, one of the products of the reaction must be a gas. In addition, one of the reactants must be a solid in order to be placed in the buret so that the gas released is contained within it. Only answer choice **A.** provides a reaction that begins with a solid (Zn) and ends with a gas (H_2).

Q 159 D deduce

Since the hydrogen gas fills the top of the buret, which is surrounded by the air in the room, we assume that the gas is at room temperature.

Q 160 **A** **deduce**

Remember the ideal gas law, PV = nRT. In this experiment, P and T are constants and V is measured. The 2 remaining variables are R and n. The point of the experiment is to determine the value of R, and so we must know n (the number of moles) in order to calculate it.

Q 161 **A** **F1; PHY 9.1.4**

Using electric field (E) = voltage (V)/distance (d), we have:

$$E = V/d$$

$$\rightarrow E = 200 \text{ V}/15 \text{ cm}.$$

All answers are given in kV/m, so we will convert our units and solve:

$$E = 2 \times 10^{-1} \text{ kV}/15 \times 10^{-2} \text{ m} \rightarrow E = 2/15 \times 10^{-1}/10^{-2}$$
$$\rightarrow E = 2/15 \times 10 \rightarrow E = 20/15 \rightarrow E = 4/3$$

$$\therefore E = 1.33 \text{ kV/m}.$$

Therefore, answer choice **A.** is correct. Note that if you did not know the equation E = V/d, you could have figured out what values from the figure to use and what to do with them by looking at the units of all the answer choices (kV/m). From this we can see that the value given in volts must be divided by the value given in centimeters.

Q 162 **B** **P1**

In the wet etching procedure, the aluminum not covered by the mask is removed by acid, while in the dry etching procedure, the aluminum not covered by the mask is removed by chlorine ions. The mask is used to protect certain parts of the aluminum from the etching process. Therefore, it must not react with the materials used in etching, making answer choice **B.** correct.

Q 163 **A** **F1; deduce**

The *arrangement* of the holes has nothing to do with the rate that gas will flow through them. The passage does not say that the holes are important in pressure control or ionizing chlorine atoms, nor does it say that either of these things are necessary in the procedure. The holes in the upper electrode in Figure 1 are distributed in a uniform manner. The only thing we can deduce from this is that it distributes chlorine ions evening, allowing for a uniform etch across the wafer.

<u>Q 164</u> C PHY 9.1.2

Using Coulomb's law, $F = k(q_1)(q_2)/r^2$, where F = force, k = proportionality constant, q = charge, and r = distance between charges, we are trying to find an equation that relates F to r, and so we have:

$$F \propto 1/r^2.$$

Assuming that k, q1 and q2 are constants, we now have F inversely proportional to the square of r. Letting F_1 be the force between the two ions initially, and F_2 be the force between them after doubling the distance (r), we have:

$$F_1/F_2 = r_2^2/r_1^2.$$

Since r_2 is double the initial distance (r_1), we can substitute $r_2 = 2r_1$ into the equation:

$$F_1/F_2 = (2r_1)^2/r_1^2 \rightarrow F_1/F_2 = 4r_1^2/r_1^2 \rightarrow F_1/F_2 = 4 \rightarrow F_1 = 4\,F_2$$

$$\therefore F_2 = \tfrac{1}{4} F_1.$$

Since F_2 is a quarter of F_1, the force is decreased by a factor of 4 when the distance is doubled.

<u>Q 165</u> A CHM 1.4

The percent by mass of an element in a compound can be found by dividing the mass of the element present in the compound by the total mass of the compound. In this case:

% aluminum (Al) in aluminum trichloride ($AlCl_3$) = mass of Al in $AlCl_3$/molecular weight of $AlCl_3 \times 100\%$.

The molecular weight of Al = 27 g/mol and molecular weight of Cl = 35.5 g/mol, and so we have:

% Al in $AlCl_3$ = 1 mole Al × 27 g/mol / [(1 mol Al × 27 g/mol) + (3 moles Cl × 35.5 g/mol)]

$\rightarrow$ % Al = (27)/[(27) + (3 × 35)] $\rightarrow$ % Al = 27/[27 + 105] $\rightarrow$ % Al =27/132

$\rightarrow$ % Al = 25/130 $\rightarrow$ % Al = 1/5 $\rightarrow$ % Al = 1/5 × 100%

$\therefore$ % Al = 20%.

Note that in going from 27/132 to 25/130, we decreased both the numerator and the denominator by 2. When you have to make approximations like this, it is best to do similar things to both numbers (i.e. decrease one, decrease the other). By doing so, you don't change the final value of the equation as much. In questions where the numbers in the answer choices are very close together, you must be particularly careful in your approximations in order to come up with the correct answer. In this question, if we had approximated 27/132 to 30/130 (which is tempting because this looks easy to deal with), we would have ended up with a final value much closer to 27%, and thus may have picked the wrong answer choice.

Q 166 B P1; SI

The passage indicates that energy from solar radiation breaks down molecular O_2, a statement that is illustrated in the first reaction of Series I. Energy, h_η, is a necessary part of the reaction in which oxygen molecules are separated.

Q 167 C deduce

Answer choice **A.** is tempting; absorbing energy above the stratosphere will prevent activation of radicals in the stratosphere, thereby inhibiting the breakdown of ozone. However, energy is also vital to forming ozone in the first place, and so we cannot eliminate it. To have a stable concentration, the rate of formation of ozone must equal the rate of breakdown by active radicals (answer choice **C.**).

Q 168 A CHM 1.6

The first thing to do is figure out the oxidation number of nitrogen in NO. Since the valence of oxygen is +2 and the overall charge of this molecule is 0, the oxidation number of N must be +2. Answer choice **A.** should jump out at you because N_2 is the standard state of the nitrogen element, which means the oxidation number of N in this molecule is 0 (which is less than 2!). You should be able to figure out that the oxidation number of N in NO_2 = +4, in NO_3 = +6 and in HNO_3 = +5, all of which are greater than 2, and thus incorrect.

Q 169 D PHY 9.2.4

Recalling that Energy = h (constant) × c (speed of light)/λ (wavelength), we see that energy is inversely proportional to wavelength. This means that large wavelengths correspond to low energy. Consequently, radiation less energetic than the 230-290 nm range will be greater than 290 nm.

Q 170 A CHM 3.2

Hydrogen has one valence electron while oxygen has six. Therefore, the total number of electrons surrounding the two atoms must be seven (one dashed line = 2 electrons). Only answer choice **A.** shows a structure in which there is a total of seven electrons. The hydrogen formed a covalent bond with oxygen (indicated by one dashed line), so that the two atoms share two electrons between them (one from hydrogen, one from oxygen), leaving 5 electrons around the oxygen atom.

Q 171 B SI, SII

As a rule, the least stable molecule will be very reactive, thereby eliminating answer choices **A.** and **D.** By comparing the breakdown of the 2 molecules (the first reaction in both Series I and II), we observe that O_2 requires energy input to break it down, while O_3 breaks down without any input of energy. Therefore, O_3 is less stable and more reactive than O_2.

Q 172 C P2, L1

The passage states that ozone breaks down readily by exothermic (heat releasing) reactions, and shows this process in the Series II reactions. If these are the only reactions occurring, heat will be continually released into the stratosphere, resulting in an increase in temperature of the stratosphere.

Q 173 D P1, L6-9

The passage states that the hydrogen atoms of water have a partial positive charge while the oxygen has a partial negative charge as a result of the unequal sharing of electrons. In order to have an overall charge on the molecule, there must be an extra electron (-1) or a missing electron (+1). In this case, the molecule is neutral because electrons are not added or removed from the atoms' structures. The unequal sharing of electrons gives the molecule polarity, but not a charge.

Q 174 A P1, L10

Intermolecular bonds are between molecules, while intramolecular bonds are within molecules. Only answer choice **A.** represents an intermolecular bond (hydrogen bonds in water occur between the slightly positive H of one molecule and the slightly negative O of another molecule). Answer choices **B.** and **C.** are intramolecular because they are the bonds that hold a molecule together. Answer choice **D.** does not qualify as a bond. Hydrogen bonding occurs between a hydrogen that is bound to an electronegative atom (e.g. N,O) in one molecule and an electronegative atom in another molecule.

Q 175 A deduce

Recall that density = mass/volume. The lower density of ice means that there are less molecules of H_2O for a given volume. This could very well be the result of intermolecular bonds that hold the molecules in a crystal lattice. The molecules in a crystal lattice arrangement will be further apart than in the relatively unordered liquid form.

Q 176 B P3 (equation)

Using the K_w equation given in the passage, we get:

$$K_w = [H_3O^+][OH^-]$$

$$\rightarrow [H_3O^+] = K_w/[OH^-] \rightarrow [H_3O^+] = 1 \times 10^{-14}/1 \times 10^{-5} \rightarrow [H_3O^+] = 10^{-14}/10^{-5}$$

$$\therefore [H_3O^+] = 10^{-9} \text{ moles/L.}$$

Therefore, answer choice **B.** is correct.

Q 177 C P2

The passage indicates that water is used as a solvent for ionic and polar compounds but that it rarely dissolves nonpolar compounds. NaCl and KBr are ionic compounds, while NH_3 is an example of a polar compound, similar to H_2O. The diatomic molecule O_2 is nonpolar since the pull of one oxygen on the electrons in the bond is equal to the pull on the electrons by the other oxygen, resulting in an equal share of electrons.

Q 178 B deduce

When the temperature (and therefore the kinetic energy) of water decreases, the number of hydrogen bonds increases as the crystal lattice structure begins to form. Since the temperature of the ice water in this example does not increase despite the addition of heat, the molecules must be absorbing energy for some purpose other than increasing kinetic energy. Melting of the ice occurs when many of the hydrogen bonds break, thus disrupting the orderly arranged crystal lattice. We can infer that the absorbed energy breaks some of the hydrogen bonds in ice.

<u>Q 179</u> B deduce

The addition of water would produce an equal increase in the concentration, thereby eliminating answer choice **C.** A noble gas and a nonelectrolyte do not add either of the ions involved, nor will they react with them, leaving us with answer choice **B.** An acid will disrupt the 1 to 1 ratio of hydroxide and hydronium ions in water.

<u>Q 180</u> D deduce

When going from ice to water, some of the hydrogen bonds that help to form the crystal lattice of ice must be broken. However, water still retains many hydrogen bonds as a liquid. In order to change from liquid to gas, all of the hydrogen bonds in water must be broken because molecules in the gas phase are far apart. If it takes a set amount of energy to break one hydrogen bond, then vaporization will require a higher input of energy because more hydrogen bonds must be broken.

<u>Q 181</u> C P1, L1-2

The passage indicates that the angle between the covalent bonds is 105°. Recalling that 180° produces a straight molecules and 90° produces a right angle, we can infer that the angle of 105° gives a somewhat bent molecule. This occurs in H_2O molecules because of the 2 lone pairs of electrons on the oxygen molecule which push the hydrogens down because of electron-electron repulsion.

<u>Q 182</u> A P2, L2-6

During extraction, a second solvent is mixed with the aqueous solution and the mixture is allowed to settle. The two solvents are immiscible and so two phases will form in the solution. Compounds will be dissolved preferentially into the solvent in which they are the most soluble. The passage indicates that metal ions can only be extracted into organic solvents if they are first converted from their charged state to a neutral state. This means that the original charged ion is more soluble in the aqueous phase than the organic phase. Once the ions are neutralized, they become more soluble in organic solvents (which are uncharged and nonpolar), and thus may be extracted.

<u>Q 183</u> B P1, L6-7; CHM 4.2

To answer this question, look at the structure of ether: H_3C-O-CH_3. This molecule will not form ions and thus answer choices **C.** and **D.** are eliminated. There are no hydrogens bonded to an electronegative ion, a condition that is necessary in H bonds, thereby eliminating answer choice **A.** Van der Waals forces, caused by the interaction of transient dipoles, are weak forces likely present in ether. Even if you did not know the structure of ether, the passage states that the molecules are held together by weak forces. You should know that Van der Waals forces are weak forces, while H bonds are quite strong.

<u>Q 184</u> C deduce

You should notice right away that the answers do not require us to complete the calculation, which will save us some much needed time on the exam. Since the ions present in 200 ml of water are extracted into the smaller volume of chloroform (10 ml), the original concentration of Pb^{2+} (25 ppb) will increase by a factor of 200/10 if all the ions present in water are extracted into the chloroform. Since the extraction is 98% efficient, the concentration of Pb^{2+} ions will be slightly less. The equation must be multiplied by the 98/100, or 0.98. Only answer choice **C.** includes each of these factors.

<u>Q 185</u> D F1

To obtain the best separation, we want to be in a pH range to get maximum extraction of one ion (e.g. as close to 100% as possible) without any extraction of the other. From Figure 1, a pH of approximately 2.5 extracts 100% of Pb while 100% of the Zn ion can be extracted at a pH of 4.5.

<u>Q 186</u> A deduce

Ideally, we would like to have a pure sample of a substance during analysis to avoid the skewing of results by other compounds present. Overcoming intermolecular forces is not required for analysis, nor does this occur during extraction. Conversion to a neutral species is not necessary for analysis either; this is done only to make extraction possible. Extraction also does not cause substances to be in a state of disorder.

<u>Q 187</u> D P2, L6-8

You should know from reading the passage that the purpose of the chelating agent is to neutralize the metal ions so that they may be soluble in organic solvents. The chelating agent does not act as a catalyst. The passage states that the cationic metal ions are neutralized by forming complexes with the chelating agent. The cations mentioned are single charged atoms and therefore cannot form dipoles. This means that they can't form the complex with the chelating agent through such weak attractive forces as Van der Waals forces. The only way this complex can occur is through the donation of electrons by the chelating agent to the positively charged cations.

Q 188 A P1 (reaction); CHM 9.8

The equilibrium constant is the ratio of products to reactants of a reaction (K_{eq} = [products]/[reactants]). In this reaction, quinine in ether is considered the product (it is on the right in the equation), and therefore this must be in the numerator of the equation, making answer choice **A.** correct.

Q 189 B CHM 8.9

Entropy (S) is a measure of the disorder of the system, where S increases with increasing disorder. Whenever a substance undergoes a change from a solid to a liquid state (as occurs in dissolving quinine in ether), S increases because the molecules of a liquid are less orderly arranged than the molecules of a solid.

Q 190 D F1

From Figure 1, an increase in pH corresponds to an increase in ion extraction, and thus a decrease in the concentration of ions remaining in aqueous solution. The most extraction of ions out of the aqueous solution will be accomplished at the highest pH, which is given in answer choice **D.**

Q 191 C P2

The pH of the solution of vinegar and dye is determined by the amount of protons released into the solution by vinegar. Using pH = -log [H^+] for vinegar:

$$pH_{vinegar} = 2.5 \text{ (given in the passage)}$$
$$\rightarrow pH = -\log [H^+] \rightarrow 2.5 = -\log [H^+]$$
$$\rightarrow [H^+]_{vinegar} = 10^{-2.5}.$$

Since 10 ml of vinegar is added to 80 ml of dye, the [H^+] of pure vinegar is diluted by a factor of 10/90. Therefore, the pH of the mixture is:

$$\boxed{pH_{mixture} = -\log [H^+]}$$

$$\therefore pH_{mixture} = -\log [10^{-2.5} \times 10/90].$$

Therefore, answer choice **A.** is correct.

Q 192 D E4

Answer choice **A.** can be eliminated since the marble chips do not acquire color in the solution and consequently, are not identical to calcite (eggshell) in reactivity. Answer choice **C.** is incorrect because a shift in equilibrium to the right would involve an increase in dye on the egg, not the "white blotches" or "little color" observed. The acidic solution explanation given in answer choice **C.** might explain the bubbles seen in Experiment 1, where pH is being adjusted. However, this does not explain the bubbles seen in Experiment 2, where there is no reason to believe that the marble chips have made the solution excessively acidic. The only satisfactory explanation for both experiments is that the calcium carbonate of the eggshell is reacting with acid present in the dye to produce carbon dioxide and water.

Q 193 A E3

In the graph for Experiment 3, we can see that increasing amounts of NaCl correspond to diminished action of the dye (lighter colors). Therefore, NaCl must somehow interfere with the dyeing process. Proteins in acidic solutions have a protonated positively charged terminal amino group and a neutral terminal carboxyl group, leaving an overall positive charge on the molecule. The anionic dye used in the experiment likely interacts with the protein coat through electrostatic interactions, which can be disrupted by the association of salt ions between these charged molecules.

Q 194 D deduce

To study the effect of dye concentration on egg color, the concentration of dye in the vinegar-dye mixture must be varied. The only thing suggested in the answer choices that will affect the concentration of dye is varying the amount of water added to the stock solution. Adding a lot of water will dilute the stock solution and make the concentration of dye lower. Adding very little water will make the concentration of dye higher.

Q 195 B deduce

Distillation is a technique used to separate liquids on the basis of their boiling points. A mixture is heated gradually and each component will vaporize at a characteristic temperature. The steam is collected and condensed to produce a relatively pure compound. If the boiling point of two components is similar, they will vaporize together and produce a mixture after condensation, thus distillation is ineffective in separating the components.

Q 196 D **deduce**

A catalyst is a compound that increases the rate of a reaction without being consumed in the overall reaction. The catalyst does not affect properties of the reaction such as equilibrium and enthalpy (H).

Q 197 D **CHM 4.2**

The induction of polarization (e.g. a dipole) in a molecule and the subsequent attraction of the molecule to the inducer is referred to as (big surprise) a dipole-induced dipole force.

Q 198 D **deduce**

Answer choices **B.** and **C.** can be eliminated since the addition of benzene (C_6H_6) does not affect the pH of the column. It is not likely that an increase in the amount of benzene caused ionization (recall that benzene is very unreactive). Since the amount of benzene flowing out of the column depends on the amount of benzene binding to the glass beads, it is likely that the larger amount of benzene caused the binding sites on the column to become saturated (occupied), leading to the spreading of benzene along the column.

Q 199 B **P4 (equation)**

K′ = (moles adsorbed solute/g glass fiber column)/(moles of solute in solution/ml of solution). Using just the units for this equation, we get:

$$K' = (\text{mol/g})/(\text{mol/ml}) \rightarrow K' = \text{mol/g} \times \text{ml/mol}$$

$$\therefore K' = \text{ml/g}.$$

Therefore, answer choice **B.** is correct.