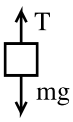
Annotated Answers to the Multiple Choice Section of the 2004 AP Physics B Exam

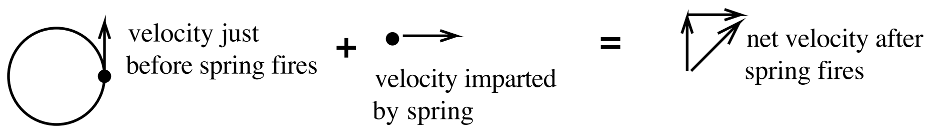
1. E. Circular motion is *always* accelerated, as is simple harmonic motion (indeed, uniform circular motion is one example of simple harmonic motion.) However, simply because an object is moving in a straight line does not guarantee non-acceleration; imagine dropping an object, for example.

2. B. Draw a free-body diagram;



It is clear that T – mg = F_{net} = ma, so T = mg + ma = m(g + a). We are told T ≤ 50 N, and letting the value of g = 10 m/s^2, then mg = 30 N, or m = 3 kg, and 50 N ≥ (3 kg)(10 m/s^2 + a), or a ≤ 6.7 m/s^2.

3. E. The spring will impart a velocity in the *x* direction to the ball. The ball, at the moment shown, has a velocity tangent to the circle, in the positive *y* direction. Adding an *x* velocity to the ball's *y* velocity produces a velocity up and to the right. See the diagram:



4. E. A variant on a famous trick question. The *velocity* of an object thrown straight up is zero at its highest point, but its *acceleration* is *not* zero, it's the constant –g, 9.8 m/s^2 downward! Answer (A) is wrong because "equilibrium" implies that the net force is zero, and the net force on the ball is mg downward. Answer (B) is wrong as explained. Answers (C) and (D) are wrong because both momentum and kinetic energy depend on the speed, and both are zero at the highest point.

5. B. The net force on the object is 0 N, because the object is suspended. There are three forces acting on the object; tension, gravity and Archimedes' buoyant force. These must add up to zero. The tension is 3 N. The mass is 0.4 kg, so the gravitational force on the mass is 4 N, hence the buoyant force must be 1.0 N.

6. A. A tricky question. Answer (B) is clearly wrong, because at the point of release, each sphere will be momentarily at rest. Answer (C) sounds pretty good; in fact, it is correct for the pendulum's mass; but for the spring's mass, the minimum gravitational energy is attained at its lowest point, not the midpoint. For the same reason answer (D) is wrong; it is true for the pendulum's mass, but not for the spring's. Finally, the total energy doesn't have either a *maximum* or a *minimum*; it is constant. Both masses have the same energy throughout (in the idealized case that air resistance is zero.)

7. E. The period of the pendulum is given by $T = 2\pi\sqrt{\frac{m_1}{k}}$, and the period of the spring is $T = 2\pi\sqrt{\frac{\ell}{g}}$. Setting these equal to each other, and solving for k, gives k = $m_1 g/\ell$. In fact this problem could almost be answered by dimensional arguments; k must have the units of N/m, so only (D) and (E) are options.

8. E. An odd question, especially given the preceding question. If a student gets #7. right, it is unlikely she or he will miss #8. The formula for the period is given above, and it depends only on *m* and on *k*. It is a famous principle that in simple harmonic motion, the amplitude has *no effect at all* on the period of oscillation.

9. C. The order in which the masses are dropped is immaterial. The initial momentum is Mv_o. The final momentum will be (M + 3m)v_f. These will be equal, no matter how the extra masses are dropped in. That means v_f will have the same value, (Mv_o)/(M + 3m) in both cases.

10. B. The relevant formula is g = GM/R^2. If M is doubled, and R is also doubled, then

$$g' = G(2M)/(2R)^2 = (2/4)\,GM/R^2 = g/2,$$ so the new weight would be 500 N/2 = 250 N.

11. D. You have to read the problem carefully. By definition, $v_{avg} = \Delta x/\Delta t$ = (8 – 2) m/(2 – 1) s = 6 m/s.

12. C. It's sometimes called "The Zeroth Law of Thermodynamics": two objects in thermal equilibrium (at the same temperature) with a third object must be in thermal equilibrium with each other.

13. A. The question is asking: "Which of these quantities are *state functions*?" State functions are those quantities that depend only on values of the state variables (P, V, T); if you know what state the gas is in (that is, you know the value of the pressure, volume and temperature of the gas), then you know the value of a state function: the path taken to reach a point on a PV diagram does not matter. (In mechanics, the same property is true for work done by a conservative force: it is path-independent.) Neither heat, Q, nor work, W, are state functions; that's why there are different formulas for Q and W depending on the type of process (adiabatic, isobaric, and so on) used to take the gas from one state to another. Energy, however, depends *only* on the temperature, so it is a state function, independent of path.

14. C. There is a formula for the force between two current-carrying wires;

$$F = 2k' I_1 I_2 \ell / R$$

from this it's obvious that doubling the current in each wire will increase the force by a factor of 4. Alternatively, if you don't know the formula, you can figure it out like this. The force on one wire is proportional to the product of the current I_1 in that wire and the magnetic field B_2 of the other wire; but that depends on the current I_2 in that wire. So the force is proportional to the product of the currents. Actually, by symmetry, it has to be like this; so doubling each current must increase the force by four times.

15. A. Inside a conductor (it doesn't have to be a sphere, and it doesn't have to be hollow) the electric field due to static charges is zero.

16. A. Answer (B) is completely false; the potential difference (or voltage) across each capacitor in parallel is the same, but the charge on each depends on its capacitance. Answer (C) is true only for capacitors in parallel; in series, the net capacitance is less than the smallest capacitance. Answer (D) is false; capacitors in parallel combine like resistors in series, but capacitors in series combine like resistors in parallel. Answer (E) is false; adding the capacitors increases the effective area of the capacitors, but not their separation.

17. B. There is a formula for the resistance of a wire; $R = \rho L/A$, where L = the length of the wire, and A is its cross-sectional area. If the radius is cut in half, the area decreases by 4 times. This increases the resistance by 4 times. Cutting the length in half decreases the resistance by 2 times. The net is an increase of 2 times. Alternatively, if you don't remember (or know) the formula, it should be obvious that R increases with length, and decreases with cross-sectional area.

18. E. Efficiency is defined as (Work out)/(Energy in) or what is the same thing, (Power out)/(Power in). The electrical formula for power is $P = IV = (0.5\ A)(120\ V) = 60\ W$. The power out is mechanical, $P = Fv \cos\theta = (9\ kg)(10\ m/s^2)(0.5\ m/s)(\cos 0) = 45\ W$. The efficiency = (45 W/60 W) = 0.75 = 75%.

19. D. The Principle of Superposition: the electric field due to the two charges is the vector sum of the field due to each separately. From the charge $+Q$ we have at the origin a field straight down; from the charge $–Q$ we get at the origin a field to the right. The sum of these two vectors makes a vector down and to the right, at an angle of –45°.

20. D. From $+Q$, we have at the origin $\mathbf{E} = kQ/d^2\ (0, –1)$; from $–Q$, we have at the origin $\mathbf{E} = kQ/d^2\ (1, 0)$. The vector sum of these two gives $\mathbf{E} = kQ/d^2\ (1, –1)$. The magnitude of this vector is $\sqrt{2}\, kQ/d^2$.

21. E. The rule about electrical forces is $\mathbf{F} = q\mathbf{E}$. The electron and the proton have a charge exactly the same size (though of opposite sign), and so the size of the forces acting on each is the same. But the other answers are easily shown to be wrong. Since each is released from rest, the electron will go to the right, and the proton to the left. (Recall that the definition of the direction of **E** is the way that a *positive* test charge gets pushed.) This means (A) is wrong. The electron has a mass about 2000 times less than the proton, so its acceleration, its speed and its displacement will all be much larger. That rules out (B), (C) and (D).

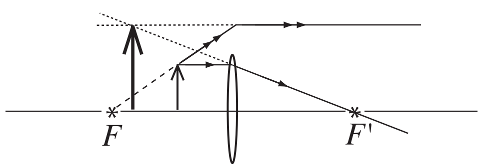
22. D. A variant on a famous problem. Drill a hole in a metal plate, and heat it up. The plate expands. Does the hole get larger or smaller? It gets *larger*; the heating is uniform, so simply imagine a slightly larger model of the original, and it will have a correspondingly larger hole. The key is *uniform expansion* (or contraction if the temperature is made less.) Note that the diameter is exactly 0.1 of the side, so in the new, expanded plate, the diameter will still be 0.1 of the side; the new diameter will thus be 0.101 m.

23. C. Recall that the pressure a gas exerts on the walls of a container is made up of the collective impulses $\Delta \mathbf{p} = m\Delta \mathbf{v}$ of all the collisions of the gas molecules against the walls. If the average speed of these molecules is increased, the impulses will increase proportionally, and the pressure will increase. The density of the gas is the number of molecules divided by the volume of the container: neither N nor V changes, so the density is the same, and both (A) and (B) are wrong. The temperature of the gas will also increase, because the average kinetic energy of the gas is proportional to the temperature, and if the average speed increases, so will the average kinetic energy, and hence the temperature will increase. Hence (E) is also wrong.

24. B. A spherical mirror does not have a true focal point, but so long as the rays are all near to the axis, there is a point that acts like a focus, located at R/2, where R is the radius of the sphere. If *c* is the center of curvature, *b* seems about halfway to the surface from *c*.

25. B. The "first harmonic" is also called the "fundamental". The rule is that the second harmonic has a wavelength exactly half as long as the "fundamental", and so also a frequency twice that of the "fundamental". If this second harmonic has a frequency equal to *f*, then the fundamental should have a frequency of $f/2$. Confirm this by realizing that the third harmonic should have a frequency three times that of the fundamental, and sure enough, $3f/2 = 3 \times (f/2)$.

26. A. You should always draw a ray diagram when asked problems about light paths. Here:



The converging lens is being used as a magnifying glass; the resulting image is virtual, upright and larger.

27. C. Radio waves are a form of light, so they travel at the speed of light, $c = 3 \times 10^8$ m/s. For light waves, $c = \lambda f$, and

$$\lambda = c/f = (3 \times 10^8 \text{ m/s})/(100 \times 10^6 \text{ /s}) = 3 \text{ m}.$$

(Both the value of c and the meaning of M as a prefix are given to you on the data page.)

28. E. Light waves are *transverse*, with oscillations taking place perpendicular to the direction of motion; sound waves are *longitudinal*, with oscillations occurring along the direction of motion. Light waves travel at c, while sound waves (in air at standard pressure and temperature) travel at Mach 1, about a million times slower. Light waves can be polarized, but not sound waves. *All* waves can exhibit interference effects.

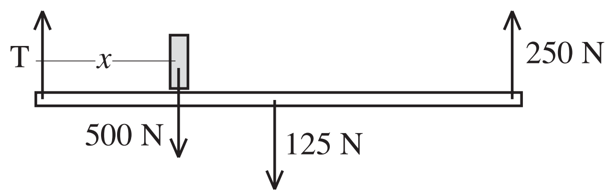
29. A. This was a strange question. Find the slope by drawing a straight line on the test booklet graph (perhaps using the edge of your answer sheet), and finding the rise over the run. You can pretty much do this by inspection; ΔF is about 20 N, and Δt is definitely 4 seconds. Then the slope is 5 N/s. I don't understand why the possible answers didn't include 2 N/s or 3 N/s or some other values less than 5 N/s.

30. C. The question is asking about *impulse*; $F\Delta t = \Delta p$. The impulse in this problem is the *area* under the *F* vs *t* graph from $t = 0$ to $t = 4$ seconds. The area is roughly (0.5)(5 N + 25 N)*(4 seconds) = 60 N-s.

31. E. This is the same principle as air bags in cars. The change in kinetic energy and momentum of the person will be the same (since the initial speed is some v_o, and the final speed is zero) whether there is an air mattress or not.

Recall Galileo IV: $2a\Delta x = v^2 - v_o^2 = - v_o^2$; if you can increase the *distance* over which the deceleration occurs, you necessarily decrease the deceleration, and increase the time. This can be a life-saver, since $F = ma = m\Delta v/\Delta t$, and if Δt is big, F is small.

32. B. The examiners provided no picture for this problem (and they should have done so.) So draw one yourself:



The two chains together must provide enough upward force to balance the downward forces of 625 N, so the left chain must exert a force upward of 625 N – 250 N = 375 N.

33. B. The board is 4 m long. Take torques about the left edge. The downward (clockwise) torques are 500 N times x and 125 N times 2 m. The upward torque is only 250 N times 4 m. (The torque due to the left chain is zero, because we are taking torques about the left end, and the distance from the left chain to the left end is zero. That is, if the board is not to rotate, we need

$(500\text{ N})\, x + (125\text{ N})(2\text{ m}) = (250\text{ N})(4\text{ m})$, or dividing everything by 125 N gives

$4x + 2\text{ m} = 8\text{ m}$; in which case $x = 3/2\text{ m} = 1.5\text{ m}$.

(Torque problems are rare; you might see one every two or three years.)

34. A. The graph (A) is the standard for the photoelectric effect; just label the y axis with "K_{max}" of emitted electrons, and the x axis with "f" of incident light, and you have the graph that is always used to describe the effect. Note that the line does not go through the origin, but instead begins at a "threshold frequency"; no electrons are emitted until the photons have enough energy to do the work needed to pull the electrons away from the positive charges of the metal nuclei.

35. D. The intensity of the light is proportional to the energy delivered per second (the power) by the light. Since the light has a fixed frequency (it is "monochromatic", or one color), and all the photons therefore have the same energy, it follows that the intensity measures *the number of photons* per second. Each photon can kick out one electron, so the intensity determines the number of electrons per second that will be kicked out of the metal. But the number of electrons per second is essentially the current, so the intensity of light will be directly proportional to the current. (Note: it is necessary that the frequency of this light be greater than or equal to the "threshold frequency", otherwise *no* electrons will be emitted. The problem says that the frequency is above "the cut-off frequency", which we can take as synonymous with threshold frequency.)

36. C. As nuclei get heavier, they tend to have the number of neutrons larger than the number of protons, for example, U^{235}; Uranium is element number 92, so it has 235 – 92 = 143 neutrons.

37. E. The pressure is given by $P = P_o + \rho gh$. Since all the containers have the same height, filled with the same liquid, it follows that the pressure at the bottom of each container is the same for all of them. The net force on the bottom is given by F = PA, but if all the A's are the same, and all the P's are the same, then all the F's are the same.

38. A. Bernoulli's Principle. We know that where the velocity is large, the pressure is small. The narrow neck of the tube forces the air flow to move rapidly, so the pressure in the tube will be less than atmospheric, and this will cause the level of the water to rise a little, pushed up by the greater atmospheric pressure outside the tube.

39. E. A tough problem. Let the force exerted up by the spring scale be denoted F. In air, we have $F - mg = 0$, so $F = (0.45\text{ kg})(g)$. In water, we have, according to Archimedes' Principle, ($B = F_{buoyant} = \rho Vg$)

$$F - mg + \rho Vg = 0, \text{ or } (0.36\text{ kg})g = (0.45\text{ kg})g - \rho Vg; \text{ so } V_{rock} = (0.09\text{ kg})/\rho$$

where ρ is the density of water. The density of the rock equals (m/V), so

$$\rho_{rock} = (m/V_{rock}) = (0.45\text{ kg})/((0.09\text{ kg})/\rho) = 5\rho = 5 \times 10^3\text{ kg/m}^3$$

since the density of water is 1000 kg/m^3.

40. B. A simple case of momentum conservation. Before the spring expands, we have $\mathbf{p}_{total} = \mathbf{0}$, so

$$\mathbf{p}_{total} = m_A\mathbf{v}_A + m_B\mathbf{v}_B = \mathbf{0} = \mathbf{p}_{total}' = m_A\mathbf{v}_A' + m_B\mathbf{v}_B';$$

$$m_A\mathbf{v}_A' = -m_B\mathbf{v}_B' \text{ or } m_A(5\text{ m/s}) = -m_B(-2\text{ m/s}) = m_B(2\text{ m/s}), \text{ so}$$

$$m_A/m_B = 2/5.$$

41. A. A simple case of Newton's Law. The problem asks only about the horizontal acceleration. The horizontal force to the left is (30 N) cos 60 = 15 N. The force to the right is 10 N. The net force is 5 N to the left, and the acceleration is F/m = (5 N)/(10 kg) = 0.5 m/s^2.

42. B. For uniform circular motion, $a = v^2/R = (2\pi R/T)^2/R = 4\pi^2R/T^2$, a formula that comes up frequently in gravity.

43. E. The period of the mass on the spring will not be affected; $T = 2\pi\sqrt{m/k}$. The period of the mass on the pendulum *will* be affected; $T = 2\pi\sqrt{\ell/g}$. On Planet X (who comes up with these dumb names?) the gravity will be twice as large, because $g_{Planet} = GM/R^2$. If the mass of Planet X is twice Earth's, but its radius is the same, then $g_X = 2g_{Earth}$. That means the pendulum period will be *shorter*, while the spring period will be the same.

44. E. If an object moves in uniform circular motion, then the net force is toward the center of the circle, and the acceleration is likewise toward the center of the circle (and equals v^2/R). (The examiners were certainly partial to choice (E) in 2004...)

45. D. Potential is a linear function between capacitor plates. Point *P* is one-fourth of the way from the bottom plate, at 2 V, to the top plate, at 10 V. There is a voltage of 8 V difference between the plates, so *P* would be one-fourth of this difference, or 2 V, of the way from the starting potential of 2 V. That is, *P* will be at 4 V. (Had *P* been exactly halfway between the plates, it would have been at a voltage exactly halfway between the two potentials of the bottom and the top, namely 6 V.)

46. D. The electric field between capacitor plates is everywhere the same, equal to V/d = (10 – 2)V/(0.04 m) = 200 V/m.

47. C. Faraday's Law, coupled with Ampère's Law. The loop on the right is moving parallel to the wire, so it is always experiencing the same magnetic field in the loop; the flux in this loop does not change, so no current is generated in it. The loop on the left is moving away from the wire, so the flux in the loop is changing; the magnetic field is getting smaller. The magnetic field through the loop is into the plane of the paper (by the second Right Hand Rule). Since the loop is losing X's, the current acts to compensate for the loss of X's by choosing to flow clockwise.

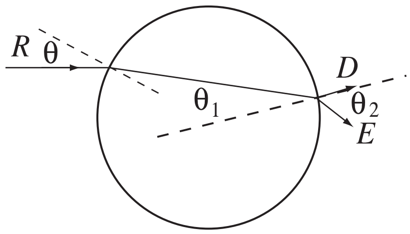
48. D. The resistors R_2 and R_3 are in parallel, so add them in reciprocals;

$$1/R_{net} = 1/2000 + 1/6000 = 4/6000 = 1/1500 \text{ or } R_{net} = 1500\ \Omega.$$

The circuit has a net resistance of 1500 Ω + 2500 Ω = 4000 Ω. The current is I = V/R = 12 V/4000 Ω = 3 mA.

49. A. All of the current must pass through the 2500 Ω resistor. Then it splits up, with three times as much going to the 2000 Ω resistor as to the 6000 Ω resistor. That is, $I_1 > I_2 > I_3$.

50. E. Snell's Law. Since glass has a greater n than air, the bottommost path must be the one taken. Then, in emerging, the angle must be greater outside the sphere than inside, which is path E. See the illustration.



We have to have θ_1 smaller than θ_2 since $n_2 < n_1$. The only choice is E. (The angle at D is very nearly zero.)

51. A. Again, Snell's Law. Now the angle has to be larger inside the sphere, so that means the upper branch, ending in either A or B. Drawing the normal at the place where A and B fork, you can see that A corresponds to a smaller angle outside the sphere than inside.

52. A. Doppler Effect. The distance away has nothing to do with the frequency; only the speed of the source matters.

53. E. A *very* tough problem; only 9% of the candidates got it right. The relevant formula is, for a maximum,

$2d = (j + {}^1/2\, f)\,\lambda$ (thin films: λ to be preferentially reflected)

where j = 0, 1, 2, ... , f = the number of phase inversions ("flips"), d = the thickness of the film, and λ is the wavelength of the light inside the film. Phase inversions occur when light in a medium of index n_1 reflects off a medium of index n_2, where $n_2 > n_1$. In the present case, there is only one inversion, when the incident light reflects off the thin film. When a beam reflects off the bottom of the thin film, it does not invert, because the index of the film is larger than the index of the second medium. That is, f = 1. Then we can have

$2d = (0 + {}^1/2)\,\lambda$ or $2d = (1 + {}^1/2)\,\lambda$ or $2d = (2 + {}^1/2)\,\lambda$ and so on,

which leads to $d = {}^1/4\,\lambda$, $d = {}^3/4\,\lambda$, $d = {}^5/4\,\lambda$ ... and so on. The only possible choice is E.

54. E. Use the standard formula for lenses and mirrors: $1/f = 1/d_o + 1/d_i$. Then $1/2 = 1/8 + 1/d_i$; $1/d_i = 3/8$, and $d_i = 8/3$.

55. D. Even half the lens will give the full image, no less sharp, but dimmer, because half of the light does not reach the image.

56. D. Do it by analogy. This most closely resembles a *resistor*. The difference between the temperatures is like the difference in electrical potential (or voltage); the wall is like a resistor, which gets more resistive as the area decreases; and the heat is like the charge. In a resistor, we'd have a smaller transfer of charge (a smaller current) if the area were smaller and the potential difference were smaller. So, by analogy, decreasing A and decreasing the difference $T_2 - T_1$ will decrease Q. (Actually, increasing d should also decrease Q; so one option should have been "decreasing A, decreasing $T_2 - T_1$ and increasing d "., but that option was not given.)

57. A. ΔE = Q + W; in this problem, W = – 32 J, and Q = – 16 J, so ΔE = – 48 J.

58. E. The energy before is the sum of mc^2 for all the masses plus K_n , the kinetic energy of the neutron. The energy after is the sum of mc^2 for all the masses plus K, the kinetic energy of all the products. Then

$$K = (mc^2)_{reactants} - (mc^2)_{products} + K_n = (\Delta m)c^2 + K_n;$$

the energy equivalent of the mass decrease plus the initial kinetic energy of the neutron.

59. E. The reaction may be written

$$\mathrm{Pb}^{214}_{82} \rightarrow e^{0}_{-1} + X^{214}_{83}$$

For nucleus X, the mass number N is 214, the same as Pb, and the atomic number Z is 83, increased by 1.

60. C. Dimensional analysis. 50,000 W is 50,000 J/s. A photon of wavelength 4 m has a frequency of (c/4 m) = 7.5 x 10^7 Hz, and an energy of hf = (6.63 x 10^{-34} J-s)(7.5 x 10^7 Hz) = 50 x 10^{-27} J. The number of photons is

(50,000 J/s) / (50 x 10^{-27} J/photon) = 10^{30} photons/sec.

61. C. We need to analyze this pretty carefully in order to do the next problem as well.The object starts at rest. For the first second, **F** = (ma, 0), so **v**= (F/m t, 0); i.e., v_x = (F/m) t, v_y = 0. The final value of v_x is (F/m)(1 s). In the next second, **F** = (0, ma), so v_x does not change from its value at the end of one second, and v_y = (F/m) t. At the end of the two seconds, the velocity has the value v_x = (F/m)(1 s), v_y = (F/m) (1 s), so it looks like (C).

62. B. During the first second,

$$K = 1/2\ mv^2 = 1/2\ m(v_x^2 + v_y^2) = 1/2\ mv_x^2 = 1/2\ m((F/m)\ t)^2 = (F^2/2m)\ t^2$$

which is clearly a parabola in time. At the end of the first second, v_x attains a final value of $F^2/2m$. Now the acceleration acts in the *y* direction, and we have

$$\mathbf{v} = (F/m, F/m\ t) = (F/m)(1, t)$$

$$K = 1/2m(v_x^2 + v_y^2) = (F^2/2m)(1 + t^2)$$

which is *another* parabola, beginning at t = 1 second. The graph is (B).

(In my opinion, this problem was too mathematical for the B test; only 25% of the candidates got it right.)

63. D. Astonishingly, this was the most challenging problem on the test; only 7% of the candidates solved it. If you are not careful, you may conclude that *no* energy is lost. But in fact, as you can show with calculus, collisions in which the two objects stick together lose more kinetic energy than any other type of collision. Let's do the problem, with momentum conservation:

$$p_{total} = Mv - (2M)v = -Mv$$

$$p_{total}' = (M + 2M)v' = 3Mv' = -Mv;\ \text{so}\ v' = -1/3\ v$$

The original kinetic energy is

$$K = 1/2\ Mv^2 + 1/2\ (2M)(-v)^2 = 3/2\ Mv^2$$ and the final kinetic energy is

$$K' = 1/2\ (3M)(1/3\ v)^2 = 1/6\ Mv^2$$

so the loss in kinetic energy is $3/2\ Mv^2 - 1/6\ Mv^2 = 4/3\ Mv^2$.

If however you neglect the minus sign in the first equation, you find that the final velocity is apparently *v*, so that there is no loss at all of kinetic energy. My guess is that a lot of people did this. Don't forget: momentum, and velocity, are both *vectors*; direction matters.

64. D. Recall that the flux $\Phi_B = BA\cos\theta$. This will change sign every 180°, or six times in three complete turns.

65. D. Work = qV = ΔK = $\frac{1}{2}$ mv^2 – $\frac{1}{2}$ mv$_o^2$ = $\frac{1}{2}$ mv^2, since the charge is initially at rest. Initially, the work is QV. In the second case, the work is (2Q)V = 2QV which is twice the work as in the first case. Since the work equals the kinetic energy, the second kinetic energy is twice the initial kinetic energy. That the mass in the second case is half what it was in the first case has *nothing* to do with the work done, and hence nothing to do with the final kinetic energy. It *does* affect the final velocity (twice in the second case what it was in the first), but not the kinetic energy. (Sneaky devils... The examiners are *not* your friends.)

66. D. The charge at Y is positive and that at Z is negative, because the field lines demonstrate how a *positive* test charge would be pushed at that point. (Test charges are *always* positive, and don't you forget it!) That makes (A) wrong. (B) is wrong because the field lines are not parallel lines, as they would be in between the plates of a capacitor. (C) looks good, but the field is strongest where the lines are closest together, for example immediately to the left of Y or immediately to the right of X. (E) is nonsense because the lines go toward Z and away from Y.

67. C. This problem can *almost* be done by finesse. Since all objects fall at the same rate, *the mass of the satellite should not matter*. The only answer that does not have the satellite's mass *m* in it is (C). It can also be done, laboriously, by dimensional analysis. The easiest is just to use Newton's Laws:

$F_{net} = mv^2/r = GMm/r^2$; cancel m/r and obtain the famous satellite equation, $v^2 = GM/r$, or $r = GM/v^2$.

68. E. A triviality, *if* you know the formula P = Fv cos θ = (900 N)(4 m/s) cos 0 = 3600 W.

Say you don't know the formula. No problem. Power is Work/Time. We don't know how much work is done since we don't know how far the dang block is pushed. So, *make up a number*. Who's gonna stop you? (If we knew the angle the ramp was inclined at, we could at least estimate the length of the ramp from its height, but noooo, they didn't tell us that.) The speed is 4 m/s, so let's say we push the block for two seconds, or 8 meters. Then the work done is (900 N)(8 m) = 7200 J, and divide by 2 seconds, presto! 3600 Watts.

If they don't give you something, the chances are good that you don't need it; and if you think you *do* need it, why, make it up! It will almost certainly cancel. In fact we can even let it be a variable. In this case, call it Δx, and we can see it cancel out: the work done is 900N*Δx, the time needed is Δt = Δx/(4 m/s), so (900N*Δx)/(Δx/4 m/s) = 900 N*4 m/s = 3600 W.

69. C. Again, a triviality *if* you know the formula that v = E/B for a charge to move undeflected through crossed magnetic and electric fields. If you don't know this formula, you can derive it very readily. The magnetic force on the charge is qvB sin 90 = qvB, upwards by the first Right Hand Rule. The electric force on the charge is qE downwards. If the charge moves in a straight line, then these forces must be equal;

qE = qvB, or v = E/B = (6 N/C)/(2 T) = 3 m/s.

70. A. It is surprising that only 13% of the students got this right. You should know that *outside* of a uniformly charged sphere, the electric field acts precisely like a point charge. (*Inside* a uniformly charged sphere, or *any* conductor, spherical or otherwise, the electric field is ... you know, right? ... *zero.)* And what is the electric field of a point charge? Easy:

$E = kq/r^2 = (9 \times 10^9 \text{ N-m}^2/\text{C}^2)(4 \times 10^{-6} \text{ C})/(2 \text{ m})^2 = 9 \times 10^3$ N/C.

Here's the breakdown by topic:

Topic	*Problems*	*Actual &*
Mechanics	1–11, 29–33, 40–44, 61–63, 67, 68	26/70 = 37%
Fluids	37–39	3/70 = 4%
Thermodynamics	12, 13, 22, 23, 56, 57	6/70 = 8.5%
Electricity & Magnetism	14–21, 45–49, 64–66, 69, 70	18/70 = 26%
Optics, Waves & Sound	24–28, 50–55	11/70 = 16%
Nuclear & Quantum	34–36, 58–60	6/70 = 8.5%