	Basic Idea	Solution	Answer
#1.	$y = y_o + v_o t + \frac{1}{2}at^2$ here a = - g, a constant	The graph is a single parabola that is concave downward because the coefficient of the quadratic term is negative. the conditions of Newton's First Law of Motion.	B
#2.	$F = G\dfrac{Mm}{r^2}$	Solving the general equation for r give us $R = \sqrt{\dfrac{GMm}{W}}$ and making the substitutions $W = F$ $R = r$ gives $R = \sqrt{\dfrac{GMm}{W}}$. If instead we put in *W/2* we will have $r = \sqrt{\dfrac{GMm}{W/2}} = \sqrt{\dfrac{2GMm}{W}}$ so clear *r* differs from *R* by a factor of $\sqrt{2}$.	B
#3.	Free fall acceleration. ($\Sigma\vec{F} = m\vec{a}$)	This could be thought of as an example of Newton's Second Law of motion. The acceleration is proportional to and in the same direction as the (near constant) force of gravity.	E
#4	Components $\Sigma\vec{F} = m\vec{a}$	Since the conditions of the question state that we are to assume that air resistance is negligible, the only force, and therefore acceleration, for the object is downward and constant.	E
#5.	For rotational equilibrium: $\Sigma\vec{\tau} = 0$ where $\tau = rF\sin\theta$	(3 m)(120 N) – (4 m)(*F*) = 0 therefore *F* = 90 N. buoyant force is then 4N-3N = 1N.	C
#6.	Definition	Inertia is the opposition that a body offers to any attempts at changing its state of motion.	D
#7.	Energy Conservation $K = \frac{1}{2}mv^2$; $\Delta U = mgh$	The speed is greater when the kinetic energy is greater. That occurs when the potential energy is least.	B
#8.	Gravitation Centripetal Force	Clearly the force of gravity is unopposed, and there is an acceleration and therefore a force toward the center of the circle.	E
#9.	Energy Conservation $K = \frac{1}{2}mv^2$; $\Delta U = mgh$	Taking $U = 0$ at $h = 0$, the total mechanical energy at point A is $K + U = 0 + mgh_A$ and when substituting $K = U$ in the total energy we have $K + U = 2U$ which gives $2U = mgh_A$ and this U will occur at $h_A/2$. The closest labeled point is at *C* that appears to be only slightly lower than that. (Choice D could be a distracting choice but "negligible friction" would account for C being a bit lower than half-way, but nothing would account for the kinetic energy being more than half of the original potential energy as it would be at D.)	C
#10.	$PV = nRT$ ($K = \frac{3}{2}kT$)	Temperature for an ideal gas is directly proportional to the internal kinetic energy. For an ideal gas this is the only internal energy. The product of $P_bV_b = P_cV_c$ therefore the temperature is the same at both Points. It follows that there is no change in internal energy.	C
#11.	$W = -P\Delta V$ $\Delta U = Q + W$	For *ab* there is no change in volume, so no work is done on the gas. The First Law of Thermodynamics give $\Delta U = Q + W$ = 1 000 J + 0J = 1 000 J.	D
#12.	In general metals are the best conductors of heat and electricity	Heat transfer by conduction is usually greater for more dense material, and the "electron gas" in metals quickly carries the kinetic energy through the material.	C
#13.	$E = \dfrac{F}{q}$ $F_{net} = ma$	Here then, $a = \dfrac{F}{m} = \dfrac{qE}{m} = \dfrac{(9\times10^{-9}\text{ C})(5\,000\text{ V/m})}{4.5\times10^{-5}\text{ kg}} = 1.0\text{ m/s}^2$	D

#14. $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$ & fields inside conductors with static charges.

This equation for the electrical field *outside* of a spherical charge distribution easily follows from Coulomb's Law and the definition of electric field intensity. E is proportional to the charge. Because there is not charge inside the conducting shell the field in that region remains zero. **D**

#15. $W_{net} = \Delta K$, $F_B = qvB$ and the right-hand rule.

Because the force on moving charges exerted by constant magnetic fields is always perpendicular to the motion of the moving charges, they can do no work on the charge. Here then, the electric force must account for all of the work and therefore the change in kinetic energy, 11 μJ- 9 μJ = 2 μJ. **C**

#16. $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$

The electric field intensity, E , is a vector quantity. Here the sum of the fields due to the two charges is zero so they must be in opposite directions. Because the charges are on opposite sides of *P*, the only fields of like charges will be opposed at that point. Because the field is inversely proportional to the square of the distance, the larger distance to a_2 must be compensated for by a $q_1 < q_2$. **E**

#17. *P=IV* and *V=IR*

Solving for *R* and substituting for *I* from the first equation yields…

$$R = \frac{V}{I} = \frac{V}{P/V} = \frac{V^2}{P} = \frac{(120\text{ V})^2}{60\text{ W}} = 240\ \Omega$$

D

#18. Induced charges. *E* is zero inside of conductors with static charges and the charges reside on their surfaces. Conservation of charge.

The net field being zero inside the conductor means that the field of the +*Q* charge and the field on the inside of the shell, Q_i, must add to zero, that is

$$E_{+Q} + E_{Q_i} = \frac{1}{4\pi\varepsilon_o}\frac{+Q}{r^2} + \frac{1}{4\pi\varepsilon_o}\frac{Q_i}{r^2} = 0 \text{ therefore } Q_i = -(+Q)$$

By conservation of charge then the charge on the outer surface must be +*Q*.
(Note: Gauss's Law would be a quick solution but it is not required for AP B.) **C**

#19. *E* is zero inside of conductors with static charges. $E = -\Delta V/\Delta r$

Because *E* is zero within the shell we have $\Delta V = -E\Delta r = 0$. V is the same throughout the shell. A less abstract solution is that if there were a difference In potential there would be a current. That would shortly bring the situation into an equilibrium situation where in turn the difference in potential would be zero. **D**

#20. Resistors in Series and Parallel

$R_s = R_1 + R_2 + \ldots + R_n$

$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$

$\Delta V = IR$

For the parallel portion: $R_P = 5\ \Omega$. That is series with the 5 Ω resistor gives a total resistance of 10 Ω. Using Ohm's Law solved for *I* we have $I = \Delta V/R = (100\text{ V})/10\ \Omega = 10\text{ A}$. **D**

#21. Components, Free fall acceleration

The net force acting each ball is gravitation so they both experience an acceleration of magnitude *g*. The horizontal velocity does not have an Effect on the time each ball take to reach the ground. **E**

#22. $v = v_o + at$, $x = x_o + v_o t + \frac{1}{2}at^2$

From the first equation it is clear that doubling the time will double the speed. This does not match choices A) or B). The second equation tells us that if $v_o = 0$, as it is here, the change in position is proportional to the square of the t. Therefore X will travel four times as far as Y. **E**

#23. $H = \frac{kA\Delta T}{L}$

Since *H* and *A* are to be the same for the same presumed temperature difference, we can write $\frac{k_w}{L_w} = \frac{k_c}{L_c}$. Solving for we get $L_w = L_c (k_w/k_c)$. Substituting the given yields L_w= 40 cm(0.1 W/m•K)/0.8 W/m•K) = 5 cm. **C**

#24. *PV=nRT*

Solving for *P* the equation becomes $P = \frac{nRT}{V}$ so plotting *P vs. 1/V* would yield a straight line for constant temperature. **D**

#25.	$\frac{1}{s_i}+\frac{1}{s_o}=\frac{1}{f}$	Because $s_i = s_o$ = 12 cm we quickly get $\frac{1}{f}=\frac{1}{12\text{ cm}}+\frac{1}{12\text{ cm}}=\frac{2}{12\text{ cm}}=\frac{1}{6\text{ cm}}$ and f = 6 cm.	C
#26.	Definition of period and frequency. $T=\frac{1}{f}$	The period is given as 0.2 s, so the frequency = 1/0.2s =5 Hz	D
#27.	superposition and interference	I. occurs when the two leading downward parts match. II. Is not possible because the downward portions are each longer than the upward portions and could not be totally destroyed. III. occurs after the downward portions have passed and the two upward Portions match.	C
#28.	Constructive and destructive interference	Reference the historical Young's double slit experiment.	C
#29.	$f\lambda=v$	The velocity in glass is less than the velocity in air. The frequency cannot change because the number of waves striking the surface each second must be equal to the number penetrating the surface each second. It follows from the equation than the left side can only be reduce by a decrease in wavelength.	A
#30.	$E=hf$ *and* $f\lambda = c$	$f=\frac{c}{\lambda}$ substituted into the first equation gives $E=\frac{hc}{\lambda}$. This tells us that the larger changes in energy will be associated with the smaller wavelengths.	C
#31.	alpha and beta decay	The loss of eight alpha particles, ${}^{4}_{2}\text{He}$, means a reduction in mass number of 8×4 or 32 and a reduction in atomic number of 8×2 or 16. The beta decays result in no mass number changes but the six electrons, betas, are the result of 6 neutrons decaying into 6 additional protons. ($n \rightarrow p + e^{-} + \nu$). That means the total reduction in mass number is then 32 and the atomic number is decreased by 16 - 6 or 10.	C
#32.	Conservation of charge and mass	The total initial mass number is 9 and the total atomic number (positive charge of the nuclei) is 4. All of the choices meet these sums except for B) where the atomic numbers add to three (two from the two ${}^{3}_{1}\text{H}$ and one from ${}^{1}_{1}\text{H}$).	B
#33.	An inelastic collision $K=\frac{1}{2}mv^2$	Without doing the calculations for conservation and momentum, it should be recognized that this "sticks together" situation is always an inelastic collision and kinetic energy is lost. Then, since the mass in motion is increased this must be the result of a decrease in speed.	A
#34.	$p=mv$ $K=\frac{1}{2}mv^2$	In order to eliminate v from the equations solve the momentum equation for v getting $v=p/m$ and substitute this in the kinetic energy equation. $K=\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{p}{m}\right)^2=\frac{1}{2}\frac{p^2}{m}$	A
#35.	$T_p=2\pi\sqrt{\frac{\ell}{g}}$	Because the mass is irrelevant, the only possibility is that the length be the same.	A
#36.	**This item was not scored.**		-
#37.	$A_1v_1=A_2v_2$ [ρ = *constant*] $A=\pi r^2=\pi(d/2)^2$	The quantity Av is the volume flow rate. If the diameter of the pipe is half as great, its area will be one fourth as great and the speed must Increase by a factor of four to compensate.	E

#38. $A_1v_1 = A_2v_2$ [ρ = constant]
$A = \pi r^2 = \pi(d/2)^2$

$A = \pi(d/2)^2 = \pi(2.00\times10^{-2}\text{m}/2)^2 = \pi \times 10^{-4}\text{m}^2$. And the volume flow rate, Av, was given as 2.00×10^{-3} m^3/s therefore $v = (2.00 \times 10^{-3}\ \text{m}^3/\text{s})/\ \pi\times10^{-4}\text{m}^2 = 20/\pi$ m/s

E

#39. $P = P_o + \rho gh$

From the equation it is clear that here the height of the water is the only important variable.

C

#40. $F_G = mg$
equilibrium: $\Sigma\vec{F} = 0$

The weight of the object F_G = (3.0 kg)(9.8 m/s^2) ≈ 30 N.
$F_S + F_B - F_G$ = 20. N + F_S – 30 N = 0. Therefore F_S = 10 N

A

#41. $speed = \frac{d}{t}$

$F_G = -G\frac{m_1m_2}{r^2}$

$\frac{T^2}{r^3} = \text{constant}$

$\left[a_C = \frac{v^2}{r}\right]$

Because the distance traveled in one circular orbit = $2\pi r$, I. is clearly true. From Newton's Law of Gravitation II. Is also true. The easiest way of determining that III. is also true is from Kepler's Third Law of planetary motion T^2/r^3 = constant. If the student is unaware of that law then it can be derived in the Newtonian form using the expression for centripetal acceleration. That would consume a significant amount of time.

E

#42. $W_{net} = \Delta K$
$K = \frac{1}{2}mv^2$

$$W = \Delta K = K_f - K_i = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = \frac{1}{2}(3\text{ kg})\left[(3\text{ m/s})^2 - (5\text{ m/s})^2\right] = -24\text{ J}$$

A

#43. $W = F\Delta x\cos\theta$
$v_{av} = \frac{v_f + v_i}{2};\ v_{av} = \frac{\Delta x}{\Delta t}$

Noting that θ=180° and therefore the cosine is -1, then solving for F we have $F = -W/\Delta x$, but Δx - $v_{av}\Delta t$ and v_{av}=(5 m/s + 3 m/s)/2 = 4 m/s so F = -(-24 J)/(4 m/s)(0.5 s) = 12 N, the magnitude of the force.

B

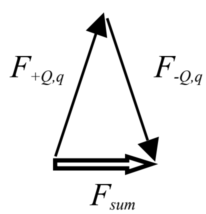
#44. Centripetal acceleration

An object moving at a constant speed in a circular path experiences an acceleration toward the center of the circle.

A

#45. $F = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}$
like charges attract and unlike charges repel
Vector addition.

Because $+Q$ and $-Q$ are equidistant from $+q$ the magnitudes of the two electrostatic forces will be equal. When the two vectors are added we get the following isosceles triangle, and it is clear that the vector sum is toward the right.



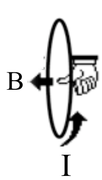
D

#46. $\mathcal{E}_{av} = -\frac{\Delta\Phi}{\Delta t}$

For a single turn of the coil then $\mathcal{E}_{av} = -\frac{(0 - 0.30\text{ T}\cdot\text{m}^2)}{2\text{ s}} = 0.15\text{ volts}$, but there are 20 turns, basically in series, so the induced emf is nearly 20(0.15 V) = 3 V.

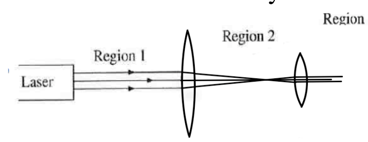
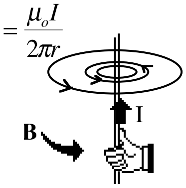
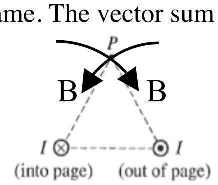
B

#47. Lenz's law
a right hand rule
such as:

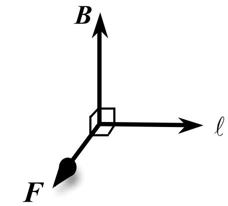


As the magnet moves to the right the flux through the coli increases to the right. Lenz's law says that the induce emf will be in such a direction as to oppose this increase. The direction of field of the induced current must be to the left in the diagram so using a right hand rule the current must be in the designated positive direction. As the magnet leaves the coil the flux of the magnet will decrease eventually becoming directed to the left. The induced current then must reverse to try to maintain the fiux to the right.

C

#48.	$n = \frac{c}{v}$ $f\lambda = v$	The frequency always remains the same because the number of waves entering the boundary must equal the number pass into the other side of the boundary. As the air is heated its density decreases. and we are told the relationship between density and the index of refraction are proportional so n is decreasing. The first equation on the left then tells us that <u>v must be increasing</u> in the air. The second equation tells us that, since f is constant, <u>λ is increasing</u>.	B
#49.	Reversability, definition of focal point *and*/or ray diagram	The two lenses are separated by a distance equal to the sum of their focal lengths so regardless of their order the rays are brought to a focus and returned to a parallel beam. Clearly the original order of lenses widens the beam. If the light were sent in the opposite direction it would concentrate the beam. Reversing the positions of the lenses amounts to exactly the same concentrating situation. 	A
#50.	$v = \sqrt{\frac{F_T}{m/L}}$ *(here m/L =* μ $F_T \equiv T$*)*	This equation does not appear on the sheet provided with Part II of the exam, and the *Course Objectives* specifically state that the student)needs to be able to <u>qualitatively</u> describe the speed of waves on a string and the speed of sound. The equation does, however, provide a clear summary of the factors involved. The length L is only important as it relates to the mass.	E
#51.	$v=f\lambda$	Solving the equation for frequency and substituting in the speed of light we have $f=c/\lambda=(3.0 \times 10^{8}$ m/s)/(6.0 × 10^{-7} m) = 5.0 × 10^{14} Hz	E
#52.	$C = \frac{Q}{V}$; $U_C = \frac{1}{2}CV^2$	From the first equation $Q=CV$ it is clear doubling V will double Q if V is not changed. Under those circumstance it is also clear that from the second equation U_C will be also be doubled.	D
#53.	$C_P = \sum_i C_i$ $\frac{1}{C_s} = \sum_i \frac{1}{C_i}$	For one parallel sections C_P = 30 μF + 30 μF = 60 μF. For the other we get C_{P2} = 20 μF + 20 μF = 40 μF. Putting these two equivalences in series we get $\frac{1}{C_s} = \frac{1}{60\ \mu F} + \frac{1}{40\ \mu F} = \frac{5}{120\ \mu F}$ and C = 24 μF.	B
#54.	Conservation of momentum. $\vec{p} = m\vec{v};\ K = \frac{1}{2}mv^2$	$\vec{p}_A + \vec{p}_B = 0$ gives us that $p_A = p_B$. Substituting $p=mv$ into the kinetic energy equations give us $K = \frac{1}{2}\frac{p^2}{m}$ Since the momentum is the same for both, clearly the object with the greater mass has less kinetic energy.	A
#55.	$\sum \vec{F}_{ext} = 0 \rightarrow \Delta\vec{p} = 0$ Def. of an elastic collision: ΔK=0	For collisions with no external forces momentum is always conserved. Mechanical kinetic energy is only conserved in elastic collisions.	C
#56.	$B = \frac{\mu_o I}{2\pi r}$ 	Because P is about equidistant from both wires the size of their magnetic fields will be the same. The vector sum of the fields at P is downward. 	A

#57. Right hand rule for the force on a current carrying wire in a magnetic field.



In this question the current (conventional) is directed toward the left in the field therefore ℓ is toward the left. B is given as into the paper so the force is directed toward the bottom of the page. E

#58. $B = \frac{\mu_o I}{2\pi r}$ The current can be determined from the strength of the magnetic field surrounding the wire at a measured distance from the wire. An ammeter would require a break in the wires to insert the meter. B

#59. $F\Delta t = \Delta p$ This is a basic statement of Newton's second law of motion. A

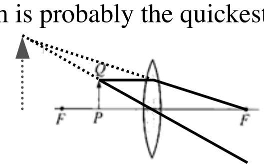
#60. Components The vertical component of the velocity is clearly zero at the highest point, but since there is no net force or acceleration in the horizontal direction, the horizontal component of the velocity remains constant at $v_x = v_o cos\theta$ = (20 m/s)(cos60°) = 10 m/s. The speed then is just this value. B

#61. $K_{max} = hf - \phi$ From the basic equation it is clear that the frequency, f, and the work function, ϕ, play a role while the intensity does not. D

#62. $U = \frac{1}{4\pi\varepsilon_o}\frac{Qq}{r}$ Because the charge on the nucleus is positive and that on the electron is negative the potential energy itself will always be negative, with a value of zero at infinity. As the electron moves away from the nucleus, that is as n increases, the potential energy will become less negative so it is increasing. A

#63. evidence for both models for different situations. examples: interference indicates wave aspects and not particle behavior, but the photo-electric effect indicates particle and not wave behavior. D

#64. A ray diagram Doing a ray diagram is probably the quickest way to answer this. D



#65. Snell's Law; Law of Reflection

A) exiting ray from material of higher index of refraction to one of lower index of refraction should bend away from the normal.
B) The internal ray clearly passes through the center of the sphere is normal to both surfaces. For this to be true it would have to enter the sphere and exit the sphere normal to the surfaces.
C) The angle of reflection is not equal to the angle of incidence.
D) It is very clear that the incident angle and angle of reflection are not equal for either reflection.
E) no problems here. E

#66. $x_m \sim \frac{m\lambda L}{d}$ This is the form of the equation provided with the Part II of the exam. Of course the student would have to know it or derive it since that list is not provided with Part I. Solving for λ and making the appropriate substitutions gives $\lambda = \frac{xd}{nL}$ B

#67. Friction tends to oppose sliding. The direction friction is down the incline. There is no indication that the "sudden push" is continued so a force up the incline is not certain and should not be assumed. A

#68.	$F_{net}=ma$	The weight (force of gravity) is give as 80 N. Using g = 10 m/s^2 we have a mass of (80 N)/(10 m/$s^{2)}$ = 8 kg. Then using the net force applied by means of the scale gives 32 N= (8 kg)a, so a = 4 m/s^2.	C
#69.	$F_{net}=ma$	Perhaps it is easiest to look at this as the net external force on the system is gravitation pulling down on the 2.0 kg block. That force is then 2.0 kg(10 m/s^2) = 20 N. That force is accelerating a total mass of 6.0 kg, so we have 20 N = (6.0 kg)a, and the acceleration is 3. 3 m/s^2.	C
#70.	$a = \frac{v^2}{r}$ and $F_{net} = ma$	Combining these two equations we get and recognizing that the friction force is the net force on the car we have $F = m\frac{v^2}{r}$. Making the mass 2m would double the force required but, because the speed is squared, making the speed one half as great will reduce the force by a factor of one fourth. The combined result is to make the required friction one-half as large.	D