2019 H2 9749 Physics Paper 3

<table>
<tr><td>1(a)(i)</td><td>When air resistance is negligible, the acceleration is 9.81 ms^{-2} (downwards) and using kinematics equation,
$v_y{}^2 = u_y{}^2 + 2a_y s_y$
$(\uparrow +) 0^2 = (160)^2 + 2(-9.81)s_y$
$s_y = 1305m$
Since it only rises to 1100m, due to a decrease in vertical height travelled, there is a decrease in G.P.E, the decrease in G.P.E is due to work done by air resistance. Therefore, air resistance is not negligible.

Several ways to approach the question. You can choose to calculate the height to which the object rose, assuming no air resistance and then to compare this to the actual height. An alternative is to use an equation for constant acceleration to determine a value for the ‘average’ deceleration on the upward motion with a conclusion on whether the equation is valid.</td><td>[3]</td></tr>
<tr><td>1(a)(ii)</td><td>Energy lost by object is equal to the Loss in G.P.E
$G.P.E_{initial} - G.P.E_{final}$
$= 0.92x10^{-3}(9.81)(1305 - 1100) = 1.85J$</td><td>[2]</td></tr>
<tr><td>1(b)</td><td>$F_{net} = W + F_A$
$= 0.92x10^{-3}(9.81) + 3.4x10^{-3} = 0.01242N$
$ma = 0.01241$
$a = \frac{0.01241}{0.92x10^{-3}} = 13.5\ m\ s^{-2}$
A common error was to give as an answer the deceleration produced alone by the air resistance. It is not correct to subtract this value from the acceleration of free fall.</td><td>[2]</td></tr>
<tr><td>1(c)</td><td>To show that F_A is proportional to square of the speed v, we need to show that
$F_A = kv^2$
$\frac{F_A}{v^2} = cons\tan t$
Using 3 points (that snap to grid) on the graph, example v = 106, 120 and 140 m s^{-1} respectively, [and use coordinates that are well spaced out along the graph line.]
<table><tr><td>$\frac{F_A}{v^2} = \frac{1.5x10^{-3}}{106^2}$
$= 1.33x10^{-7}\ Nm^{-2}s^2$</td><td>$\frac{F_A}{v^2} = \frac{1.9x10^{-3}}{120^2}$
$= 1.32x10^{-7}\ Nm^{-2}s^2$</td><td>$\frac{F_A}{v^2} = \frac{2.6x10^{-3}}{140^2}$
$= 1.33x10^{-7}\ Nm^{-2}s^2$</td></tr></table>Since the values of the ratio are very close, the relationship is shown.</td><td>[3]</td></tr>
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2(a)	Gravitational force provides centripetal force $\frac{GMm}{(R+h)^2} = \frac{mv^2}{R+h}$ $\frac{GM}{R+h} = v^2$ $v = \sqrt{\frac{GM}{R+h}}$ When symbols are given, use them. Any symbol not commonly known should be defined.	
2(b)	By Conversation of Energy Total energy at R+ h from M = Total energy at infinity $G.P.E_{R+h} + K.E_{R+h} = G.P.E_{\infty} + K.E\infty$ $-\frac{GMm}{R+h} + \frac{1}{2}mv^2 = 0 + 0$ [at rest at infinity] $v = \sqrt{\frac{2GM}{R+h}}$ Alternatively, you can also use loss in G.P.E = gain in K.E to solve. Energy changes must be explained to gain full credit.	
2(c)	To be in orbit, the speed in (b) has to be equal to speed in orbit, found in (a). Since the speed in (b) is more than the speed in orbit, found in (a), it will travel off to space. Only when speed in (b) is less than speed in orbit, then it will fall to the planet's surface.	[2]

3(a)(i)

Every point on the graph obeys ideal gas law.

$$\frac{P_A V_A}{T_A} = \frac{P_B V_B}{T_B}$$

$$\frac{2800x10^{-6}}{315} = \frac{7600x10^{-6}}{T_B}$$

$$T_B = 855K = 860K(2s.f)$$

3(a)(ii)

Work done is given by area under P-V. Under constant pressure change, the area is a rectangle.
work done by gas

$$= P(V_B - V_A) = (3.5x10^5)(7600 - 2800)x10^{-6}$$

$$= 1680J = 1700J(2s.f)$$

3(b)

Using first law of thermodynamics and sum of ΔU in one cycle BCAB = 0

stage	ΔU	q	w
B to C	**0 (T constant)**		
C to A	-2520	**-2520 (given)**	**0 (given)**
A to B	2520		
	Sum ΔU ***=0 in cycle***		

4(a)(i)

Teaching points: To derive SHM equation in a given context, the following steps are followed

1. Form equation when object is at eqm
2. Form equation using N2L when displacement
3. Simplify and compare with SHM equation $a = -\omega^2 x$

Using 1. An object that is floating is at equilibrium,
Upthrust (Weight of the water displaced) = Weight of the object

$$V\rho g = mg$$

$$Al\rho g = mg$$

where *l* is the length of liquid column at equilibrium

For displacement downwards and taking downwards as positive, mg is assumed to be larger than upthrust.

$$F_{net} = mg - A(l + x)\rho g$$

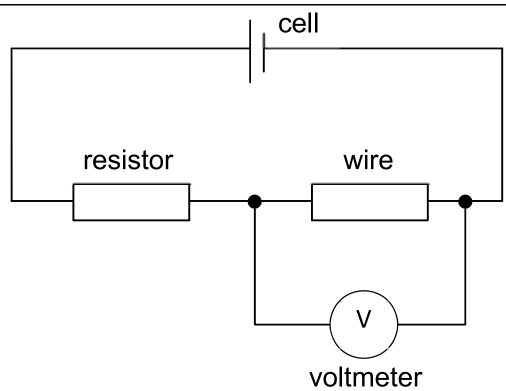
$$\text{Since } Al\rho g = mg$$

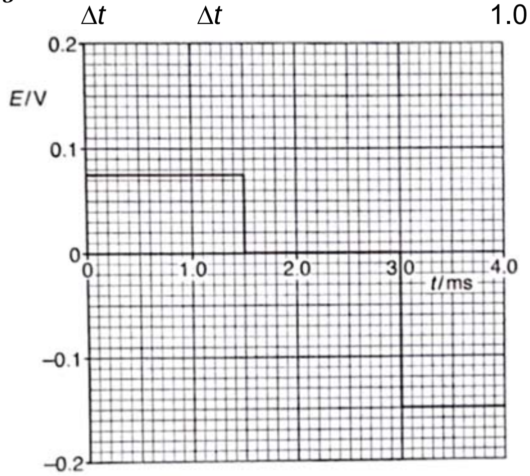
$$F_{net} = Al\rho g - A(l + x)\rho g$$

$$F_{net} = -A\rho g x$$

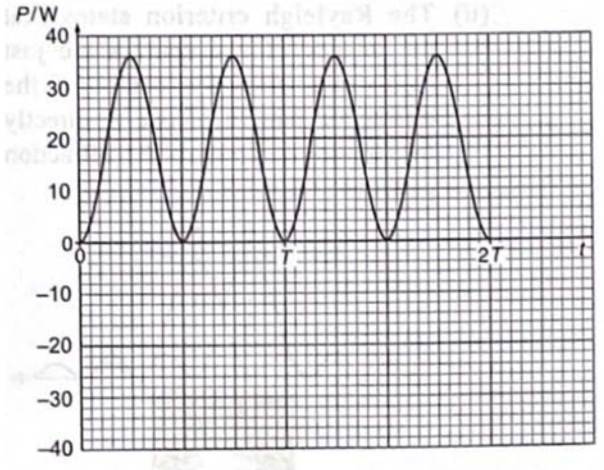
Comments: It is necessary to make clear that the resultant force would be the difference between the weight and the upthrust to get full credit. There needs to be a statement regarding the directions of the displacement and the acceleration in order to show how the negative sign arose.

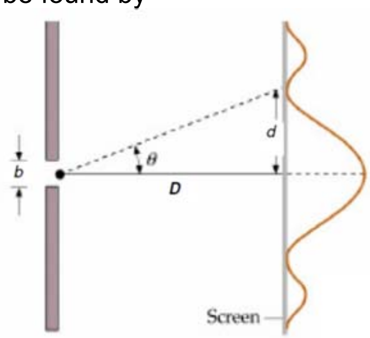
4(a)(ii)	Using 2. Using N2L $F_{net} = -A\rho g x$ $ma = -A\rho g x$ $a = -\dfrac{A\rho g}{m} x$	
4(b)	Using 3. compare with SHM equation $a = -\omega^2 x$ $\omega^2 = \dfrac{A\rho g}{M}$ $\omega = \sqrt{\dfrac{A\rho g}{M}}$ $f = \dfrac{1}{2\pi}\sqrt{\dfrac{A\rho g}{M}} = \dfrac{1}{2\pi}\sqrt{\dfrac{5.3x10^{-4}(1200)(9.81)}{0.130}}$ $f = 1.10 Hz$	

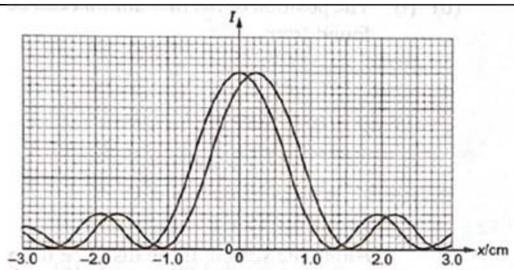
5(a)	Using Hooke's law, where *x* is the extension: $F = kx$ $27 = \left(1.8 \times 10^{4}\right) x$ $x = 1.5 \times 10^{-3}$ m
5(b)	$R = \dfrac{\rho L}{A}$ Since ρ and *A* are constants, change in $R = \Delta R = \dfrac{\rho \Delta L}{A}$ $= \dfrac{\left(3.2 \times 10^{-8}\right)\left(1.5 \times 10^{-3}\right)}{2.0 \times 10^{-7}}$ $= 2.4 \times 10^{-4}\ \Omega$
5(c)	

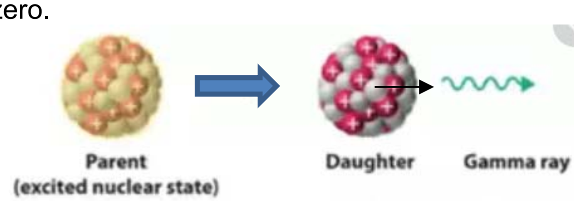
6(a)(i)	From the formulae list: $B = \mu_0 nI = \left(4\pi \times 10^{-7}\right)\left(\dfrac{900}{0.46}\right)(2.4)$ [M1] $= 5.9 \times 10^{-3}$ T [A1] Note: n is number of turns per unit length of solenoid $= \dfrac{\text{number of turns}}{\text{length of solenoid}}$
6(a)(ii)	The magnetic flux in the middle of the solenoid is parallel, however, the magnetic flux at the end of the solenoid is non-parallel and is diverging. Hence, the magnetic flux at the end is more spaced out and is weaker than the magnetic flux in the middle of the solenoid. The magnetic flux density B at the end of the solenoid is **half** that in the middle of the solenoid.
6(b)(i)	Faraday's Law of Electromagnetic Induction states that the induced e.m.f is directly proportional to the rate of change of magnetic flux linkage.
6(b)(ii)	Since the current is decreasing linearly, $\varepsilon = -\dfrac{\Delta N\phi}{\Delta t} = -\dfrac{NA\Delta B}{\Delta t} = -\dfrac{(95)\left(\pi \times 0.0080^2\right)\left(0 - 5.9 \times 10^{-3}\right)}{1.5 \times 10^{-3}} = 0.075$ V
6(b)(iii)	Between t = 3.0 ms to 4.0 ms, $\varepsilon = -\dfrac{\Delta N\phi}{\Delta t} = -\dfrac{NA\Delta B}{\Delta t} = -\dfrac{(95)\left(\pi \times 0.0080^2\right)\left(\left[\mu_0\left(\dfrac{900}{0.46}\right)(3.2)\right] - 0\right)}{1.0 \times 10^{-3}} = -0.15$ V 

7(a)	The root-mean-square value of an alternating current is the value of an equivalent steady direct current that would provide the same average power as the alternating current.
7(b)(i)	$V_{rms} = \dfrac{V_0}{\sqrt{2}} = \dfrac{24}{\sqrt{2}} = 17$ V
7(b)(ii)	From the given equation of the alternating voltage, $\omega = 440$ $2\pi f = 440$ $f = 70$ Hz
7(c)(i)	$P_{mean} = \dfrac{V_{rms}{}^2}{R} = \dfrac{17^2}{16} = 18$ W

7(c)(ii)	$P_{peak} = 2 \times P_{mean} = 36$ W 

8(a)(i)	A photon is a discrete bundle (or quantum) of electromagnetic energy. The energy of a photon is given by the product of Planck constant and frequency of the radiation (*E* = *hf*)
8(a)(ii)	Coherent light waves are light waves that have a constant phase difference. This implies that they have constant frequency.
8(b)(i)	The angle θ at which the first minimum occurs can be found by $\sin\theta = \frac{\lambda}{b}$ $\theta = \sin^{-1}\left(\frac{5.90 \times 10^{-7}}{0.15 \times 10^{-3}}\right) = 3.933 \times 10^{-3}$ rad  Along the screen, the distance between the central maximum to first minimum is *d*. $\tan\theta = \frac{d}{D}$ $d = D\tan\theta = (3.2)\tan(3.933 \times 10^{-3}) = 0.01259$ m $\therefore$ Width of central maximum = 2*d* = 0.0252 m
8(b)(ii)	When the central maximum of one image falls on the first minimum of another image, the images are distinguishable and said to be just resolved. This limiting condition of resolution is known as Rayleigh criterion.
8(b)(iii)	Since the separation of the 2 slits are only 2.3 mm apart, it means that the central maxima due to both slits are 2.3 mm apart. This is much smaller than 12.6 mm, which is the distance from the central maximum to the first minimum. Therefore the central maximum of the 2nd slit is much closer to the central maximum of the 1st slit, and does not fall on or lie beyond the first minimum of the 1st slit. The diffraction patterns are thus NOT seen as separate.

		
8(b)(iv)	Width of a fringe is equal to the fringe separation of double-slit interference pattern. $x=\frac{\lambda D}{a}=\frac{\left(5.90\times10^{-7}\right)(3.2)}{2.3\times10^{-3}}=8.21\times10^{-4}\text{ m}$	
8(b)(v)	Number of fringes $=\frac{\text{width of central maximum}}{\text{fringe width}}=\frac{0.0252}{8.21\times10^{-4}}=30$ (Answer should be 1 s.f., as stated in the question)	
8(c)(i)	Check maximum order which can be observed: $n<\frac{d}{\lambda}=\frac{(0.001\div750)}{5.90\times10^{-7}}=2.3$ Hence maximum order is 2. Central maximum occurs at 0°. First order: $d\sin\theta=n\lambda$ $\left(\frac{0.001}{750}\right)\sin\theta_1=5.90\times10^{-7}$ $\theta_1=26.3°$ Second order: $d\sin\theta=n\lambda$ $\left(\frac{0.001}{750}\right)\sin\theta_2=2\left(5.90\times10^{-7}\right)$ $\theta_2=62.3°$ Angles are 0°, 26.3° and 62.3°.	
8(c)(ii)	When the diffraction grating is unrotated, the angle separation (i.e. the difference in the angles between one order to the next) between the orders increases with the order of maxima. However, when the diffraction grating is rotated, the angle separation between the orders will be increasing on one side and decreasing on the other side.	
9(a)	Radioactive decay refers to the random and spontaneous process whereby an unstable nucleus emits an α *or* β *particle and / or* γ *photon* to become a more stable nuclide. Nuclear fission occurs when a massive nucleus (by absorbing a neutron) disintegrates into 2 smaller nuclei of similar nucleon number. Nuclear fusion occurs when nuclei of lower nucleon number combine to form a larger nucleus of larger nucleon number. Comment: Be mindful of incorrect terms and also lack of clarity between the concept of a nucleus or nuclei, a nuclide and a neutron.	[4]

9(b)(i),	Change in mass = mass of pdt – mass of reactant $\Delta m = (16.999130 + 1.007825) - (14.003074 + 4.002604) = 0.001277u$ $Energy\ E = \Delta mc^2 = (0.001277x1.66x10^{-27})(3.00x10^8)^2 = 1.91x10^{-13}\ J$	[4]
9(b)(ii)	For the reaction to take place, at least 1.91 x 10^{-13}J of energy is required, since the α particle has less energy than the energy required, reaction will not take place.	[2]
9(c)(i)	$E = \frac{hc}{\lambda}$ $\lambda = \frac{(6.63x10^{-34})(3.00x10^8)}{1.16x1.60x10^{-13}} = 1.07x10^{-12}\,m$	[3]
9(c)(ii)	Using debroglie's equation $p = \frac{h}{\lambda}$ $p = \frac{(6.63x10^{-34})}{1.07x10^{-12}} = 6.19x10^{-22}\,Ns$	[2]
9(d)(i)	By conservation of linear momentum, since the total initial momentum is zero.  From the diagram, taking right as positive $0 = p_\gamma + p_{recoil}$ $p_{recoil} = -6.19x10^{-22}\,Ns$ $K.E_{recoil} = \frac{p_{recoil}{}^2}{2m_{recoil}} = \frac{(-6.19x10^{-22})^2}{2x60x1.66x10^{-27}} = 1.92x10^{-18}\,J$	[4]
9(d)(ii)	Since the energy of the γ photon is about 10^5 times larger than that of the K.E of the recoil nucleus, energy in d(i) is insignificant compared to mass energy of the γ photon.	[1]