9749/01 H2 Physics
Multiple Choice

Question Number	Key
1	C
2	D
3	B
4	A
5	B
6	C
7	B
8	B
9	C
10	B
11	C
12	D
13	B
14	D
15	D
16	B
17	C
18	C
19	A
20	C
21	A
22	B
23	B
24	B
25	D
26	A
27	C
28	C
29	B
30	C

Question Number	Key	Solution
1	C	Option A is the approximate mass of one paper clip. Option B is the approximate mass of one coin. Option D is an unreasonable estimate.
2	D	Volume = $\pi\left(\frac{d}{2}\right)^2(h)$ Density, ρ = mass/volume =$\frac{4m}{\pi h d^2}$ $\frac{\Delta\rho}{\rho}=\frac{\Delta m}{m}+\frac{\Delta h}{h}+2\frac{\Delta d}{d}$ = 10 + 2(3) + 2 = 18%
3	B	$s=(15.0)(2.00)+\frac{1}{2}(-9.81)(2.00)^2=10.4\text{ m}$
4	A	Vertical component of 9.0 N force = 9.0 sin45° = 6.36 N < weight of crate (19.6 N), so no lifting of crate above the ground. F_{net} = horizontal component of 9.0 N force − frictional force = 9.0 cos 45° − 2.0 = 4.36 N $a=\frac{F_{\text{net}}}{m}=\frac{4.36}{2}=\underline{2.2\text{ m s}^{-2}}$
5	B	By COLM, $m_1u_1+m_2u_2=(m_1+m_2)v$ $(5.0)(4.0)+(2.0)(-3.0)=(5.0+2.0)v$ $v=\frac{20.0-6.0}{7.0}$ = 2.0 m s^{-1} Total final kinetic energy = $\frac{1}{2}(m_1+m_2)v^2=\frac{1}{2}(5.0+2.0)(2.0)^2$ = 14 J

Question Number	Key	Solution
6	C	(subscript s denotes stationary train and a denotes accelerating train) $F_s = \text{weight of mass} = 1.2 \times 9.81 = 11.772$ N When train is accelerating, the spring settles at angle to the vertical so that the horizontal component of the tension provides the resultant force for the train to accelerate. $F_a = \sqrt{11.772^2 + (1.2 \times 5.0)^2} = 13.213$ N Since force is proportional to extension, $\frac{F_s}{F_a} = \frac{x_s}{x_a}$ $x_a = \frac{F_a}{F_s}(x_s) = \frac{13.213}{11.772}(2.4) = \underline{2.7\text{ cm}}$
7	B	Minimum force needed to lift weight = 900 N Hence minimum torque needed to lift weight = 900 × 0.20 = 180 N m This torque is provided by the couple of forces *F* on the lever. Minimum force *F* = 180 / 1.20 = $\underline{150\text{ N}}$
8	B	Useful power $= 0.9 \times mgh = 0.9 \times \left(\frac{\rho Vgh}{t}\right) = 0.9 \times \left(\frac{V}{t}\right)\rho gh$ $= 0.9 \times (5.7)(1000)(9.81)(30)$ $= 1.5$ MW
9	C	Frictional force provide the centripetal force 0.2 = 0.01(0.05) ω^2 ω = 20 rad s^{-1}
10	B	Immediately after launch, spacecraft is still at/near Earth's surface, so gravitational field strength remains as *g*.
11	C	$g_E = \frac{GM_E}{r_E^2} \dots (1)$ $g_N = \frac{GM_N}{r_N^2} \dots (2)$ (2)/(1): $\frac{r_N}{r_E} = \sqrt{\frac{M_N(g_E)}{M_E(g_N)}} = \sqrt{17} = 4.1$
12	D	Loss in thermal energy of water = 0.160 × 4200 × 100 = 67200 J Mass of ice melted = 67200 / 336000 = 0.200 kg Total mass of water = 200 + 160 = 360 g
13	B	increase in internal energy = 80 + (−100) = −20 J
14	D	For the 4 options, ke and total energy are similar. gpe increases linearly with height (*mgx*). epe decreases as height increases (smaller extension) and quadratic $E_{el} = \frac{1}{2}kx^2$

Question Number	Key	Solution
15	**D**	Lower amplitude throughout. Peak shifts to a slightly lower frequency with more damping
16	**B**	Obtain from Malus's law $I = I_0 \cos^2 \theta$ and $I \propto A^2$ that $kA^2 = k(A_0)^2 \cos^2 \theta$ So, $A = A_0 \cos \theta$ Alternatively, resolve amplitude to the plane of polarisation of filter = $E_0 \cos \theta$
17	**C**	The narrower the slit, the higher the amount of spreading The longer the wavelength, the higher the amount of spreading.
18	**C**	dsinθ = nλ $\frac{0.001}{400} \sin \theta_2 = 2(567 \times 10^{-9}) \Rightarrow \theta_2 = 27.00°$ $\frac{0.001}{400} \sin \theta_3 = 3(567 \times 10^{-9}) \Rightarrow \theta_3 = 42.87°$ The angle between is 42.87 – 27.00 = 15.87°
19	**A**	From Coulomb's law, $F \propto \frac{1}{r^2}$ $\frac{F'}{F} = \left(\frac{200}{600}\right)^2 = \frac{1}{9}$ $F' = \frac{1}{9} \times 180 = 20\ \mu\text{N}$
20	**C**	Loss of kinetic energy = Gain in electric potential energy $9.0 \times 10^{-13} = \frac{79 \times 2 \times (1.6 \times 10^{-19})^2}{4\pi\varepsilon_o r}$ $r = 4.0 \times 10^{-14}$ m
21	**A**	$I = Anqv \Rightarrow v = \frac{I}{Anq}$ $v = \frac{0.30}{[1.0\times(10^{-3})^2](8.5\times10^{28})(1.60\times10^{-19})} = 2.2 \times 10^{-5}\ \text{m s}^{-1}$
22	**B**	When XJ is 0.50 m, R_{XJ} = 20 / 100 × 50 = 10 Ω V of lamp = 1.5 × (10/20) = 0.75 V $P = V^2/R$ $P'/P = V'^2/V^2$ $P' = (0.75/1.5)^2 P = 0.25P$
23	**B**	$F = BIL$ $F + 3.6 \times 10^{-3} = B(I + 4)(0.15)$ $F + 3.6 \times 10^{-3} = F + 0.6B$ $B = 0.006$ T

[Turn over

<table>
<tr><th>Question Number</th><th>Key</th><th>Solution</th></tr>
<tr><td>24</td><td>B</td><td>Option A: Force on each isotope is same, $F_B = Bqv$ (same value of force)

Option B: The isotopes have different masses.
$Mv^2 / r = Bqv$
$r = Mv / Bq$

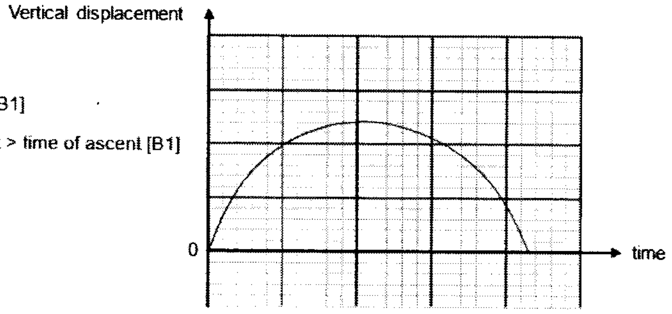
Option C: Uniform circular motion in magnetic field, so speed and k.e. remains constant for each isotope.
Option D: Acceleration $ma = Bqv$
$a = Bqv/m$ (the isotope has different mass)</td></tr>
<tr><td>25</td><td>D</td><td>$\omega = \frac{2\pi}{T} = \frac{2\pi}{\frac{1}{50}} = 100\pi$
Maximum magnetic flux linkage = NBA

Max Induced emf = ωNBA = $(100\pi)(200)(0.20)[\pi(0.1)^2]$ = 395 V</td></tr>
<tr><td>26</td><td>A</td><td>$I^2_{\text{peak}} = 10\ \text{A}^2$
P_{mean} = ½ Peak = ½ $I^2_{\text{peak}} R$
I^2_{dc} (R) = ½ (10) R
I = 2.23 A</td></tr>
<tr><td>27</td><td>C</td><td>$\phi = \frac{hc}{\lambda_0}$ (This wavelength just causes photoemission of electrons at zero kinetic energy)
$\lambda_0 = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{2.3 \times 1.60 \times 10^{-19}} = 5.4 \times 10^{-7}\ \text{m}$</td></tr>
<tr><td>28</td><td>C</td><td>$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{2.0 \times 10^{-12}} = 3.32 \times 10^{-22}\ \text{kg m s}^{-1}$
$E_k = \frac{p^2}{2m} = \frac{(3.32 \times 10^{-22})^2}{2 \times 9.11 \times 10^{-31}} = 6.0 \times 10^{-14}\ \text{J}$</td></tr>
<tr><td>29</td><td>B</td><td>The sequence of decay is not important. Deduce the total change in the proton and neutron number after the series of decay.

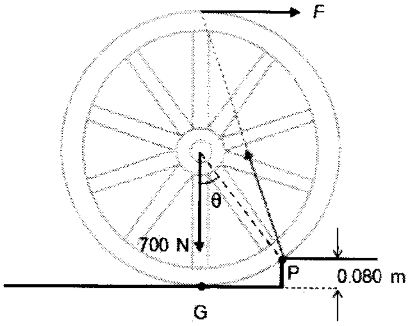
<table><tr><th>decay</th><th>proton</th><th>neutron</th></tr><tr><td>$\alpha\beta\beta$</td><td>0</td><td>–4</td></tr></table></td></tr>
<tr><td>30</td><td>C</td><td>Total number of antimony nuclei at t = 0 is N_0

After time t, $\frac{N}{N_0} = \frac{1}{3}$ which is smaller than $\frac{1}{2}$ (one half-life) and larger than $\frac{1}{4}$ (two half-lives).</td></tr>
</table>

2025 H2 Physics P2 Suggested Solution

1(a)(i)	From energy conservation, gain in g.p.e. = loss in k.e. $mg(10.0) = \frac{1}{2}mu^2 - \frac{1}{2}m(5.00)^2$ $u = 14.87 \approx 14.9$ m s^{-1}.	M1
(a)(ii)	$14.873 \cos\cos\theta = 5.00$ $\theta = 70.4°$ Or Vertical motion: $u_y = 14.9 \sin\sin q$ ↑, $a_y = 9.81$ ↓, $s_y = 10.0$ ↑, $v_y = 0$ From $v^2 = u^2 + 2as$ taking ↑ +ve: $0 = u_y^2 + 2(-9.81)(10.0)$ $u_y = \sqrt{196.2} = 14.873 \sin\sin\theta$ $\theta = 70.4°$	M1 A1 M1 A1
(a)(iii)	Consider vertical motion: $u_y = 14.873 \sin\sin 70.4°$ ↑, $a_y = 9.81$ ↓, $s_y = 0$, $t = ?$ From $s_y = u_y t + \frac{1}{2}a_y t^2$ and taking ↑+ve: $0 = (14.873 \sin\sin 70.4°)t + \frac{1}{2}(-9.81)t^2$ $0 = \left\{(14.873 \sin\sin 70.4°) + \frac{1}{2}(-9.81)t\right\}(t)$ $t = 0$ (reject) or $t = \frac{2(14.873 sinsin\ 70.4°)}{9.81} = 2.86$ s or $0 = (14.873 \sin\sin 70.4°) - 9.81t'$ $t = 2t' = 2.86$ s	M1 A1
(a)(iv)	Rate of change of momentum = resultant force = weight = mg = 8.00 x 10^{-3} x 9.81 = 0.0785 N	A1
(b)	Correct shape [B1] Time of descent > time of ascent [B1] 	

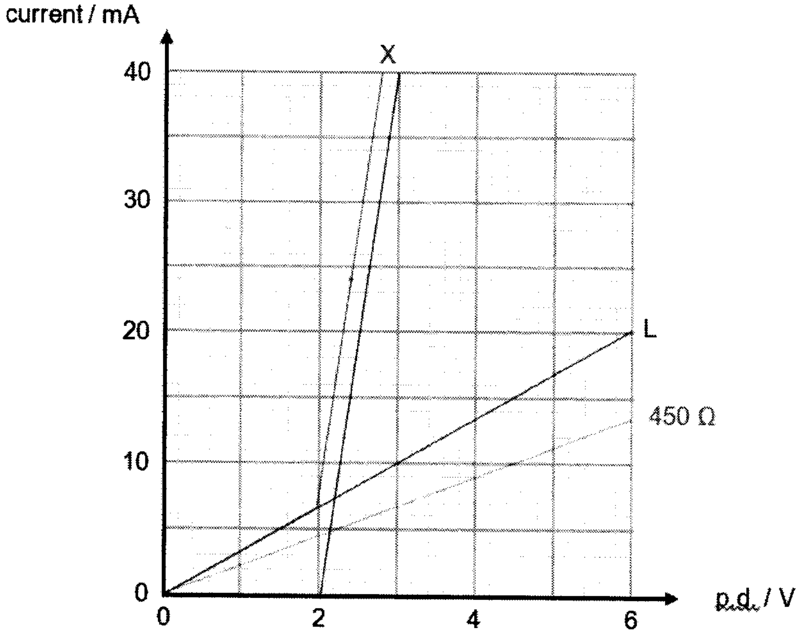
2(a)	No resultant external force acting on the two colliding / interacting objects.	B1
(b)(i)	Force on B = rate of change of momentum of B $= \dfrac{(24-20)\times10^3}{3.0-1.5}$ = 2667 ≈ 2700 N	M1 A1
(b)(ii)	Gradient is equal to the rate of change of momentum of the truck and this is also equal to the impact force exerted on the trucks according to Newton's 2nd law Since the impact forces between the two trucks are an action-reaction pair and and are of equal magnitude but acts in opposite directions, the gradients have the same magnitude but opposite signs.	B1 B1
(b)(iii)	Impulse acting on each truck (during the collision) is equal to the change in momentum of the truck. Since the impulse on the two trucks are equal and opposite, it follows that the gain in momentum of one truck must be equal to the lost in momentum of the other truck. Hence total momentum is conserved.	B1 B1
(b)(iv)	Total kinetic energy of the two trucks before collision $= \frac{(20{,}000)^2}{2\times4000} + \frac{(16{,}000)^2}{2\times2000} = 114$ kJ Total kinetic energy after collision $= \frac{(24{,}000)^2}{2\times4000} + \frac{(12{,}000)^2}{2\times2000} = 108$ kJ [C1- for calculation of KE before and after collision] Change in kinetic energy = - 6000 J (Perfectly) Inelastic collision	A1 B1

3(a)	$\cos \cos \theta \; = \frac{0.60-0.08}{0.60}$ $\theta = 29.93 \approx 30°$	M1
(b)		B1
(c)	Using principle of moments and taking moments about P: $700 \times 0.60 \, \sin \sin 30 \; = F(1.20 - 0.08)$ $F = 187.5 \approx$ 188 N = 190 N	M1
(d)	Sum forces vertically: $R_y = 700$ N Sum forces horizontally: $R_x = 188$ N $R = \sqrt{700^2 + 190^2}$ = 725 = 730 N (Accept between 725 to 730)	C1 C1 A1

4(i)	They are an action-reaction pair or they are equal in magnitude and opposite in direction.	B1
(ii)	$Mr_1\left(\frac{2\pi}{T}\right)^2 = 2Mr_2\left(\frac{2\pi}{T}\right)^2$ $\frac{r_1}{r_2} = \frac{2M}{M} = 2$	B1
(iii)	Since $\frac{r_1}{r_2} = 2$ and $r_1 + r_2 = 3.0 \times 10^{12}$ $r_1 = \frac{2}{1+2} \times 3.0 \times 10^{12} = 2.0 \times 10^{12}$ m	C1 A1
(iv)	Consider forces acting on *M*. From Newton's 2nd law and Newton's law of universal gravitation, $\frac{G(2M)(M)}{(3.0 \times 10^{12})^2} = M(2.0 \times 10^{12})\left(\frac{2\pi}{T}\right)^2$ $T^2 = \frac{(4\pi^2)(2.0 \times 10^{12})(3.0 \times 10^{12})^2}{(6.67 \times 10^{-11})(2 \times 2.0 \times 10^{30})} = 2.6635 \times 10^{18}$ $T = 1.63 \times 10^9$ s	M1 A1

5(a)	Any two of the following: • Energy is transferred along the direction of propagation of progressive waves while there is no propagation of energy in a stationary wave. • There is a propagation of the waveform (the crests/troughs/compressions/rarefactions of the waves) in a progressive wave but the waveform of a stationary wave does not move but instead undergoes changes in shape. • All particles within an internodal segment are in phase in a stationary wave while the phase difference of particles in progressive waves is proportional to their distance apart. • Amplitudes of vibrations of particles in a stationary wave vary from a minimum at the nodes to a maximum at the antinodes while the amplitude of a progressive wave (propagating in a plane) remains the same.	B2
(b)(i)	A (micro)wave (from the transmitter) is incident on the sheet and reflects at Y The incident and reflected waves overlap and superpose to form stationary wave.	B1 B1
(b)(ii)	Distance between PY = 50 x (0.5 λ) 1.5 = 50 x (0.5 λ) λ = 0.060 m	M1 A1
(b)(iii)(1)	wavelength decreases, distance between maxima/minima decreases Number of maximum amplitude increases	M1 A1
(b)(iii)(2)	wavelength is unchanged so (PQ is) the same (as QR). Distance between maxima/minima remains the same. Number maximum amplitude remains unchanged	M1 A1

6(a)	The magnetic flux density at a point in space is the magnetic force per unit length per unit current acting on a long straight conductor carrying current and placed at right angle to the field at that point. 1 marks for any 2 underlined phrases 2 marks for 3 underlined phrases	B2
(b)	Spacing between **circles** increases with distance from wire (at least three circles needed) Arrows showing direction of field is clockwise	B1 B1
(c)(i)	(each) wire lies/sits in the (magnetic) field generated/created by the other OR magnetic fields generated/created by the wires interact with each other. current (in one wire) is **perpendicular** (or not parallel) to (magnetic) field (due to other wire) so (magnetic) force acts (on wire)	B1 B1
(c)(ii)	Arrow drawn to the left of X, labelled F	B1
(c)(iii)	B-field on X due to Y = $\frac{\mu_o I}{2\pi d} = \frac{4\pi x 10^{-7}(3)}{2\pi(0.12)}$ = 5.0 x 10^{-6} T Force on X per unit length, F = BIL $\frac{F}{L}$ = 5 x 10^{-6} (2) = 10 x 10^{-6}	C1 A1
(c)(iv)	Magnetic field acting on Y by X is parallel to the wire Y. No magnetic force acts on Y.	A1

7(a)	300 Ω	A1
(b)(i)	$\frac{R}{300} = \frac{6.0-2.4}{2.4}$ or any other method R = 450 Ω	C1 A1
(b)(ii)	Resistance of the LDR increases Since current drop, pd across fixed resistor drops, OR using potential divider, potential difference across the LDR increases [B1]	B1 B1
(c)	R = V/I = 3.0 / 40 × 10^{-3} = 75 Ω	A1 A1
(d)(1)(2)	 Fig. 7.4	B1 A1

	L: straight line passing through (0,0) and (6,20) Note: The LDR follows Ohm's Law and has a resistance of 300 Ω X: same as L between pd = 0 V and 2 V, parallel to LED graph above 2 V Component X will not allow current in the LED branch but will allow the same current in the LDR branch below 2 V. Above 2 V, current in component X = sum of current in LDR and LED (accurately, we should have a curve that starts parallel to LED graph but eventually curve away from it, but this effect is not significant over this range.)	
d)(1)(2)	9.0 ± 0.5 mA	A2
	9 ± 1 mA	A1
	Find the current where the pd across X and fixed resistor (450 Ω) sums to 6 V. (Note: In a series circuit, the two components in series will have the same current flowing through them.) You will need to draw the line for 450 Ω resistance first though. Pro-tip: Place a ruler parallel to x-axis and shift it up/down.	

8(a)	energy gained by an electron with charge 1.6×10^{-19} C when accelerated / moved through a p.d. of one volt	B1 B1
(b)(i)	energy of photon = $(60 \times 10^3) \times (1.6 \times 10^{-19})$ wavelength = $(6.63 \times 10^{-34}) \times (3.0 \times 10^8) / 9.6 \times 10^{-15}$ $= 2.1 \times 10^{-11}$ or 2.07×10^{-11} m	C1 C1 A1
(b)(ii)	(incident) electrons encountering target (anode) lose energy to give several X-ray photons of lower energy / higher wavelength than **(b)(i)**.	B1
(c)(i)	energy = $10^{4.84} - 10^{4.06}$ = 57700 eV = 57.7 keV	C1 A1
(c)(ii)	Use either the proportionality constant from the Moseley for each element or compare the ratios of Z and $\sqrt{E}$. Ratios involve at least 3 elements Conclusion with valid reason	M1 M1 A1
(c)(iii)	K_β photon is created by an energy drop that is larger than the K_α photon	B1
(d)	energy is produced as heat in the target tungsten has a high melting point (so will not melt) **OR** tungsten has a high proton number greater probability of collisions between electrons and the large nucleus	B1 B1 B1 B1
(e)(i)(1)	penetrating power = ln 2 / 0.528 = 1.31 cm	C1
(e)(i)(2)	$I/I_0 = 0.40 = e^{-0.528x}$ $x = 1.74$ cm	M1 A1

(e)(ii)	$0.60 = e^{-\mu(3.87)}$ gives $\mu = 0.132$ cm^{-1}	A1
(e)(iii)	Different coefficient for different body material Coefficient affects brightness / intensity of parts	B1 B1

2025 SH2 H2 Physics Preliminary Examination

Paper 3

9749/03

Section A

1(a)	work done per unit mass in bringing a (small test) mass from infinity to that point	**B1**
1(b)(i)	correct read off of ϕ and x, e.g. $-\frac{GM}{R} = -6.3 \times 10^{7}$	**B1**
	correct equation and substitution of G, M and R, e.g. $M = \frac{6.3 \times 10^{7} \times 6.4 \times 10^{6}}{6.67 \times 10^{-11}}$ $= 6.0 \times 10^{24}$ kg (shown)	**B1**
1(b)(ii)1.	attempt to apply Conservation of Energy in any understandable form, e.g. Gain in KE = Loss in GP $\frac{1}{2}\cancel{m}v^{2} = \cancel{m}(\phi_{i} - \phi_{f})$ $v = \sqrt{2(0 - (-2.1)) \times 10^{7}}$	**C1**
	value of $\phi_{f} = -2.1 \times 10^{7}$ J kg^{-1} (read off when $x = 3R$)	**C1**
	= 6500 m s^{-1}	**A1**
	Comment: the most common mistake was substituting x = 2R. Some candidates thought the mass was in a circular orbit which is the wrong context.	
1(b)(ii)2.	$a = \frac{F}{m} = \frac{\frac{GM\cancel{m}}{x^{2}}}{\cancel{m}} = \frac{GM}{(3R)^{2}} = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{(3 \times 6.4 \times 10^{6})^{2}}$ allow also $a = g$ (ecf awarded if sub $x = 2R$)	**C1**
	= 1.1 m s^{-2}	**A1**
	Comment: similar mistake to the previous part. It is inappropriate to find the gradient on the graph as this is an approximate method. The question asks you to calculate not estimate the acceleration. The more precise method should be chosen. Also, using equations of motion is wrong as the acceleration is not constant here.	
1(b)(iii)	lower (or more negative) gravitational potential energy due to presence of the Moon	**M1**
	hence higher speed	**A1**

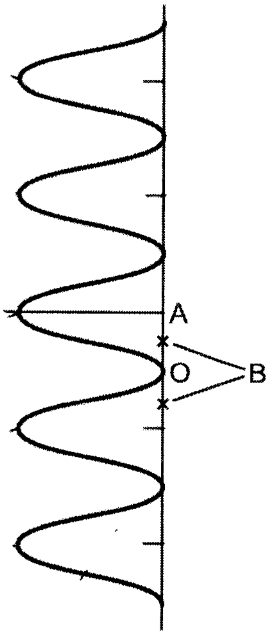
<table>
<tr>
<td>2(a)(i)</td>
<td>change in momentum of molecule per collision = $-mu - mu = -2mu$ OR
= $mu - (-mu) = \underline{2mu}$ A1</td>
</tr>
<tr>
<td>2(a)(ii)</td>
<td>average force $\left(= \frac{\text{impulse per collision}}{\text{time between collisions}}\right) = \frac{2mu}{2x/u}$ M1
$= \frac{mu^2}{x}$ (shown)</td>
</tr>
<tr>
<td>2(b)(i)</td>
<td>$W = p\Delta V$
$= (7.0\times10^5)\,[\,(20-5)\times10^{-6}\,]$ C1
$= \underline{10.5\text{ J}}$ A1

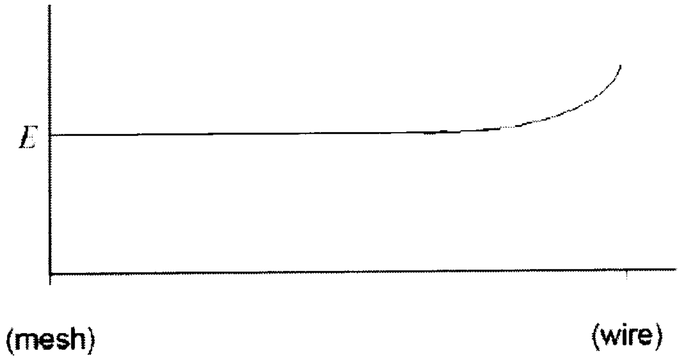
Comment: some responses perhaps thought the work done is the area within the cycle. Negative sign should not be applied as this is work done by.</td>
</tr>
<tr>
<td>2(b)(ii)</td>
<td>
<table>
<tr><th>heating supplied to gas / J</th><th>work done on gas / J</th><th>increase in internal energy of gas / J</th></tr>
<tr><td>36.8</td><td>− 10.5</td><td>26.3</td></tr>
<tr><td>− 30.0</td><td>zero</td><td>− 30.0</td></tr>
<tr><td>zero</td><td>3.7</td><td>3.7</td></tr>
</table>

third row (C → A) B1
second row (B → C) B1
first row (A → B) – value in red (allow ecf) B1
first row (A → B) – values in blue (allow ecf) B1

Comment: the sign for work done for A → B is sometimes given wrongly</td>
</tr>
<tr>
<td>2(b)(iii)</td>
<td>useful work done = 10.5 − 3.7 = 6.8 J C1
$\text{efficiency} = \frac{\text{useful work done}}{\text{total energy input}} \times 100\% = \frac{6.8}{36.8} \times 100\%$
$= \underline{18\%}$ A1

Comment: few got this correct, in particular, the energy input must be the heat supplied to the system. No process can be 100% efficient or more.</td>
</tr>
</table>

3(a)	When two or more waves meet at a point, **B1** the resultant displacement at that point is equal to the vector sum of the displacements due to the individual waves at that point. **B1** Examiner's comment: The student did not score for this question.
3(b)(i)	wavelength = $\frac{3.0 \times 10^8}{2.5 \times 10^{10}}$ **B1** = 0.012 m
3(b)(ii)1.	waves are in anti-phase at the sources and have no path difference to reach O **M1** waves meet in anti-phase at O and destructive interference occurs **A1** Examiner's comment: Many student failed to state "No path difference when the two waves reach O."
3(b)(ii)2.	path difference = $\frac{1}{2}\lambda$ = 0.0060 m **A1**
3(b)(iii)	$x\left(=\frac{\lambda D}{a}\right) = \frac{(0.012)(2.3)}{0.18}$ **M1** = 0.15 m **A1**
3(b)(iv)	point B is above or below point O such that distance OB ≈ ½ distance OA **B1** 

4(a)	electric force exerted per unit positive charge placed at that point **B1** Examiner's comment: The student did not score for this question.
4(b)(i)	For the electric potential at point P to be zero, the contribution by one sphere must be positive and the other negative, hence opposite signs of charges on spheres **M1** electric fields (due to X and Y are not zero and) must be in the same direction **A1** hence not zero Examiner's comment: The student did not score for this question.
4(b)(ii)1.	$V_X = \frac{-Q}{4\pi\varepsilon_0 x}$ $V_Y = \frac{+2Q}{4\pi\varepsilon_0 y}$ $V_X + V_Y = 0$ $\frac{Q}{4\pi\varepsilon_0 x} = \frac{2Q}{4\pi\varepsilon_0 y}$ **B1** $y = 2x$ (shown)
4(b)(ii)2.	$E = \frac{Q}{4\pi\varepsilon_0 x^2} + \frac{2Q}{4\pi\varepsilon_0 (2x)^2}$ **C1** $= \frac{3Q}{8\pi\varepsilon_0 x^2}$ **A1** Examiner's comment: The student did not score for this question. Many students did not realise that the resultant field is in the same direction.
4(c)(i)	horizontal line above zero up to at least 2/3 of the x-axis **B1** curves upwards thereafter **B1**  Examiner's comment: The student did not score for this question. Many students did not realise that the electric field is constant, i.e a horizontal line between 0 < potential < 1600 V.
4(c)(ii)	Both the electron and argon ion travels through the same potential difference and hence loses the same amount of EPE and gains the same amount of KE **M1** gain in KE of the electron = gain in KE of the argon ion

	$\frac{1}{2}m_e v_e^2 = \frac{1}{2}m_A v_A^2$ $\frac{v_e}{v_A} = \sqrt{\frac{6.64\times10^{-26}}{9.11\times10^{-31}}}$ $= 270$ **A1** **OR** gain in KE of the electron = e ΔV **M1** ½ (9.11 x 10^{-31}) v^2_e = 1.6 x 10^{-19} (4000 – 2000) -------- (1) gain in KE of the Argon ion = e ΔV ½ (6.64 x 10^{-26}) v^2_{Ar} = 1.6 x 10^{-19} (2000 – 0) ------------ (2) (1)/(2), $\frac{v_e}{v_A} = \sqrt{\frac{6.64\times10^{-26}}{9.11\times10^{-31}}}$ $= 270$ **A1** Examiner's comment: Most student obtained zero for this question. Many students gave unclear working/no substitution of values in the working/no explanation of why kinetic energy of electron is equal to kinetic of Argon ion. **<u>Zero marks were awarded</u>** to student as long as student did not give explanation/substitute values inside equation even if their numerical answer is correct.
4(c)(iii)	argon encounters more collisions than electron/ electron encounters fewer collisions than Argon OR electron is less ionising (than Argon) / argon is more ionising (than electron) and electron loses less energy (than Argon) / argon loses more energy (than electron), hence ratio is larger **B1** Examiner's comment: Most students were able to explain to answer this question. Students must appreciate besides the speed of object, other factors, i.e mass of object, distance travelled by object affects the amount of air resistance.

5(a)(i)	Induced emf $E = BLv$ or E is proportional to v where v is the instantaneous velocity of the rod. **M1** Graph showed a straight line (passing through the origin) indicating that e.m.f. varies linearly with (directly proportional to) time. Hence the rod's velocity must be increasing linearly with (directly proportional to) time. Therefore acceleration of the rod is uniform. **A1** Comments: 1. Question did not asked students to explain why an emf is induced, hence students should not be wasting time writing about changes in flux linkage / flux cutting, quoting Faraday's law and explaining why an emf is induced. 2. Those who could recall the expression $E = Blv$ were able to successfully answer the question. 3. Those who tried to explain in terms of rate of flux cutting or rate of change of flux linkage merely paraphrased the question ie "emf varies linearly with time, hence rate of change of flux linkage is constant / increase linearly with time and therefore acceleration is constant".
5(a)(ii)	kinetic energy is converted to electrical energy (to drive the current around the circuit) / thermal energy in the resistor **M1** resulting in the decrease in the kinetic energy of the rod / rod slowing down. **A1** hence external work needed to maintain constant kinetic energy / speed Comments: 1. Very few students accounted for the conversion of kinetic energy to electrical energy / thermal energy in the resistor. 2. Majority of students explained in terms of the retarding force exerted by the magnetic field on the induced current / rod causing the rod to slow down. 3. A significant number of students thought that the rod is accelerating and hence external work is needed to prevent the rod from accelerating.
5(b)(i)	period = $2\pi / 40\pi = 0.050$ s = $\underline{50 \text{ ms}}$ **A1** Comment: Most students were able to perform this calculation.
5(b)(ii)	mean power = $I_{rms}^2 R$ $= \left(\frac{3.5}{\sqrt{2}}\right)^2 (400)$ **C1** = $\underline{2450 \text{ W}}$ **A1** Comment: Most students could perform this calculation. A small but significant number of students do not know how to find the power.
5(b)(iii)	*Sine squared graph with* peaks at $\frac{1}{4}T, \frac{3}{4}T, \frac{5}{4}T, \frac{7}{4}T$ 3 marks

	Modulus of sine graph *with* peaks at $\frac{1}{4}T, \frac{3}{4}T, \frac{5}{4}T, \frac{7}{4}T$	2 marks
	Modulus of sine graph with two peaks	1 mark
	Graphs showing negative power (example sine graph)	0 mark

6(a)(i)	$E = -\frac{13.6}{2^2}$ $= -3.4$ eV	**A1**
6(a)(ii)	The negative (total) energy is a convention used to show that the particle is confined / bounded / trapped within the atom. Comments: Only a few students could score the mark. The answers that were not accepted include: 1. Electrons are negatively charged. Total energy can still be positive evenly for a negatively charged particle. 2. Electron is attracted to the nucleus. Same reason as 1. (ie total energy can still be positive). 3. Any other variety of answers that do not include the words underlined above.	**B1**
6(b)(i)	$\frac{hc}{\lambda_1} = -\frac{13.6}{3^2} - (-3.4)$ $\lambda_1 = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{\left[-\frac{13.6}{3^2} - (-3.4)\right] \times 1.60 \times 10^{-19}}$ $= 6.58 \times 10^{-7}$ m **Red** Comment: Most students could perform this calculation correctly. Common mistakes include failure to convert eV to joules or did not find ΔE. Not many students could associate 658 nm with the red end of the visible spectrum.	**A1** **B1**
6(b)(ii)	$\frac{hc}{\lambda_2} = -3.4 - \left(-\frac{13.6}{1^2}\right)$	**C1**

	$\lambda_2 = \dfrac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{\left[-3.4 - \left(-\frac{13.6}{1^2}\right)\right] \times 1.60 \times 10^{-19}}$ $= \underline{1.21 \times 10^{-7}\ \text{m}}$ **A1** Comment: Those who failed to perform the calculation in part (b)(i) correctly could not do this part as well. A significant number of students calculated 103 nm.
6(b)(iii)	All atoms that de-excite from *n* = 3 to *n* =2 will further de-excite from *n* = 2 to *n* = 1 to reach the ground state **B1** Comment: Only a small number of student stated the correct reason.
6(b)(iv)	Vertical lines at 103 nm, 121 nm and 658 nm (values of λ labelled) **B1** Height of vertical line at 121 nm = the one at 658 nm **B1** Relative separation between the 3 vertical lines **B1** Comment: Many drew x-ray spectrum (including the continuous braking radiation).

Section B

7(a)(i)	force by liquid due to pressure at bottom surface of tube = pressure of liquid at depth $h \times A$ = $\rho g h A$ **B1** Since tube is in equilibrium / no resultant force on tube, $\rho g h A = Mg$ **B1** Hence $M = \rho h A$ Examiner's comments: Several students ignored the requirement of the question to use the pressure due to a fluid and used principle of flotation instead, scoring only 1 mark for applying equilibrium concepts.
7(a)(ii)	magnitude of $F_{\text{net}} = \rho(h+x)Ag - Mg = \rho(h+x)Ag - \rho hAg = \rho Agx$ For downward displacement, upthrust > weight, hence upward resultant force. For upward displacement, weight > upthrust, hence downward resultant force Hence F_{net} is opposite to x, and $F_{\text{net}} = -\rho Agx$ (OR Taking downwards as positive, $F_{\text{net}} = W - U = Mg - \rho Vg = \rho hAg - \rho(h+x)Ag = -\rho Agx$) correct magnitude of F_{net} (with correct working) **B1** correct direction of F_{net} (either through explanation or careful handling of sign convention) **B1** (By Newton's 2nd Law,) $a = \frac{F_{\text{net}}}{M}$ **B1** $a = -\left(\frac{\rho Ag}{M}\right)x$ **A0** Examiner's comments: Several students have trouble applying the concept of a resultant force to the question. For such students, drawing a free body diagram is an important intermediate thinking tool to help. Another odd observation is the weak explanation of how the negative sign came about. Many students simply state that acceleration (or resultant force) opposite to displacement, leading to circular reason in the next part when students infer from the negative sign that accleeration and displacement are opposite.
7(a)(iii)	Since ρ, A, g and M are constant, the magnitude of acceleration a is proportional to the magnitude of displacement x **B1** The negative sign indicates that the direction of acceleration a is opposite to the direction of displacement x. Hence tube is performing simple harmonic motion. **B1** Examiner's comments: Students need to explain according to the context and use the key features of the equation they have derived.
7(a)(iv)1.	Comparing $a = -\left(\frac{\rho Ag}{M}\right)x$ with $a = -\omega^2 x$ $\omega^2 = \frac{\rho Ag}{M}$ **C1** $(2\pi f)^2 = \frac{1.2\times10^3\times5.3\times10^{-4}\times9.81}{0.130}$ **C1** $f = 1.1\ \text{Hz}$ **A1** Examiner's comments: Oddly, a handful of students attempted the use of Equations of Motion which is wrong given acceleration is not constant.

7(a)(iv)2.	energy of oscillation $= E_{\mathrm{k\,max}} = \frac{1}{2}m(\omega x_0)^2 = \frac{1}{2}(0.130)\left(\frac{1.2\times10^3\times5.3\times10^{-4}\times9.81}{0.130}) \times (0.0130)\right)^2$	**C1**
	= 0.000527 J	**A1**
7(b)(i)	constant power spread over a larger wavefront	**B1**
	hence lower intensity and lower amplitude	**B1**
	Examiner's comments: Several students mention energy loss. But wave motion is essentially a phenomenon of energy loss from an oscillating water molecule to its surrounding water molecules (albeit usually with an energy input to maintain constant amplitude, in this case, a dipper is used). Students are to note that it is usually a misconception to talk about energy loss in the context of wave motion and refer to the increasing area of the wavefront with distance.	
7(b)(ii)	$\Delta\theta = \frac{\Delta x}{\lambda} \times 2\pi = \frac{2.0}{1.0} \times 2\pi = 4\pi$ rad	**M1**
	Since the phase difference is an integral multiple of 2π rad, the dipper and the water 2.0 cm away are in phase	**A1**
	OR	
	$\Delta x = 2\lambda$	**M1**
	Since the path difference is an integral multiple of wavelength, the dipper and the water 2.0 cm away are in phase.	**A1**
7(b)(iii)	periodic curve with wavelength 1.0 cm	**B1**
	graph passes through (2,−4), (2.5,3.2), (3,−2.6), (3.5,2.2) and (4,−2)	**B1**
	Note: At 2.0 cm, in-phase with dipper means also negative maximum displacement (negative amplitude).	
7(b)(iv)	constant amplitude and periodic with period of 0.50 s	**B1**
	graph starts at (0,−2.6)	**B1**
	Note: At 2.0 cm, in-phase with dipper means also negative maximum displacement at *t* = 0 s.	
	Examiner's comments: Some students draw the graph of a lightly damped oscillation. For an oscillation in a continuous wave motion, the amplitude is constant as rate of energy propagated away is equal to rate of energy received.	

8(a)(i)	β decay: $^{209}_{83}\mathrm{Bi} \rightarrow {}^{209}_{84}\mathrm{Po} + {}^{0}_{-1}\mathrm{e}$	
	Calculate total mass of polonium and β-particle = 208.982979*u*	**M1**
	total mass of products > mass of bismuth, no β radiation	
	α decay: $^{209}_{83}\mathrm{Bi} \rightarrow {}^{205}_{81}\mathrm{Tl} + {}^{4}_{2}\mathrm{He}$	
	Calculate total mass of thallium and α-particle = 208.977031u	**M1**
	total mass of products < mass of bismuth, α radiation emitted	
	use of mass comparison between products and reactant	**M1**
	to determine that only α decay is possible	**A1**
	Examiner's comments: Oddly, several students did not make mass comparisons when the data is all about masses.	

8(a)(ii)	mass of constituent nucleons = 83 × 1.007276 + (209 − 83) × 1.008664 mass defect = 1.715173u binding energy per nucleon = 1.715173 × 1.66 × 10^{-27} × $(3.00 \times 10^{8})^{2}$ / 209 with correct conversion to eV to give 7.66 MeV Examiner's comments: Electrons are not nucleons and are not in nucleus!	**C1** **C1** **M1** **A1**
8(b)(i)	curve fluctuates/curve is jagged	**B1**
8(b)(ii)	10 min^{-1} (accept 9-11 min^{-1})	**B1**
8(b)(iii)	half-life determined at least twice half-life determined by accounting for background half-life = 1.5 hours (accept 1.4–1.6 hours) *At t = 0.1 h, count rate = 160 − 10 = 150 min*$^{-1}$*.* *expected half-life count rate = 75 min*$^{-1}$ *corresponds to 85 min*$^{-1}$ *on graph at 1.7 h* *half-life = 1.7 − 0.1 = 1.6 h* *At t = 1.3 h, count rate = 100 − 10 = 90 min*$^{-1}$*.* *expected half-life count rate = 45 min*$^{-1}$ *corresponds to 55 min*$^{-1}$ *on graph at 2.8 h* *half-life = 2.8 − 1.3 = 1.5 h* *Average half-life = 1.55 h* Examiner's comments: Not well done given that it is a simple question. Many students forget about the background count and the need to determine half-life at least twice especially given the random fluctuations of the graph.	**B1** **M1** **A1**
8(c)(i)	half-life = ln 2 / 1.44 × 10^{-11} = 4.8 × 10^{10} yr	**A1**
8(c)(ii)	$A_{\text{Rb}} / A_{\text{Rb},0}$ = exp (−1.44 × 10^{-11} × 4.0 × 10^{9}) = 0.944 valid quantitative comment that little change has occurred Examiner's comments: The second mark proves very elusive as students left their comment using the exact same words as what they are asked to show, i.e. 'almost constant'.	**M1** **A1**
8(c)(iii)	positive intercept on the *R* axis straight / curve sloping gently upwards (curve of lower gradient towards end)	**B1** **B1**
8(c)(iv)	a larger ratio implies an older sample (or references to the graph in **(iii)**) any one of the following: - need to know the initial value of *R* (or initial amount of Sr isotopes) - need to know the initial amount / percentage of rubidium Examiner's comments: There are several scripts that gave very convoluted equations which are redundant if the graph is known.	**B1** **B1**