PHYSICS — 9749

SUGGESTED MARK SCHEME

Maximum Mark: 190

October/November 2021

Paper 1
Multiple Choice

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

1 Estimate mass $\approx$ 150 g = 0.15 kg

W = mg = (0.15)(9.81) $\approx$ 1.5 N = 150 cN

Notes: centi- means divide by 100 e.g. centimetre, deci- means divide by 10 hence decimal point

2 *One tesla* is the uniform magnetic flux density which, acting normally to a long straight wire carrying a current of 1 ampere, causes a force per unit length of 1 N m^{-1} to act on the conductor.

$$1\text{ T} = \frac{1\text{ N}}{(1\text{ A})(1\text{ m})(\sin 90°)}$$

units of $B = \text{T}$

$$= \frac{\text{N}}{\text{A m}} = \frac{\text{kg m s}^{-2}}{\text{A m}}$$

$$= \text{kg A}^{-1}\text{ s}^{-2}$$

3 air resistance acts in direction opposing relative motion so left

weight acts down constantly

Vector addition gives B

4 elastic collision so special result is speed of approach = speed of separation.

Let v_x be speed of X after collision.

v - 0= 0.67 $v - v_x$

v_x = 0.33 v

5 N3L states that

force is of same *type* (gravity): eliminate **C** & **D**

force acts on another body (S acts on brick so N3L-pair *cannot* act on brick): eliminate **B** & **D**

6 forces acting on ball include tension read from newton meter, weight and upthrust

$$T + U = mg$$

$$0.75m\cancel{g} + \rho V_{\text{submerged}}\cancel{g} = m\cancel{g}$$

$$\rho V_{\text{submerged}} = 0.25m$$

$$V_{\text{submerged}}\ \left(\text{in cm}^3\right) = \frac{0.25m}{\rho}$$

$$= \frac{(0.25)(100)}{1}$$

$$\frac{1}{2}V_{\text{total}} = V_{\text{submerged}}$$

$$V_{\text{total}} = 2V_{\text{submerged}}$$

$$= 2\frac{(0.25)(100)}{1}$$

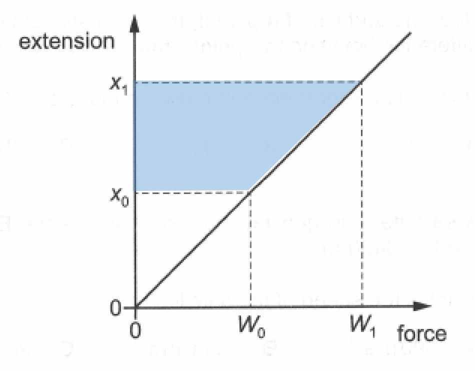
$$= 50\ \text{cm}^3$$

Notes: ball is only half-submerged

7 Always check the axis on graphs.

Area under force-extension graph gives elastic potential energy stored.

Extra potential energy is difference in "area under graph"



8 constant speed so zero net force force provided by engine has same magnitude as resistive forces

$$E = Pt$$

so work with time

$$t = \frac{s}{v} = \frac{1000}{20} = 50\ \text{s}$$

$$P_{\text{output}} = F_{\text{engine}}v$$

$$= \left|F_{\text{resistive}}\right|v$$

$$\text{KE} = Pt$$

$$= \left(\left|F_{\text{resistive}}\right|v\right)t$$

$$E_{\text{fuel}} = \frac{\text{KE}}{0.16} = \frac{F_{\text{resistive}}vt}{0.16}$$

$$m_{\text{fuel}} = \frac{E_{\text{fuel}}}{48\times10^6} = \frac{\frac{F_{\text{resistive}}vt}{0.16}}{48\times10^6}$$

$$= \frac{(400)(20)(50)}{(0.16)\left(48\times10^6\right)}$$

$$= 0.0052\ \text{kg}$$

9 magnetic force provides centripetal force

$$Bqv = mr\omega^2$$

$$Bq\left(\cancel{r}\cancel{\omega}\right) = m\cancel{r}\omega^{\cancel{2}}$$

$$\frac{Bq}{m} = \omega$$

10 field strength is numerically equal to potential gradient at that point

$$|g| = \frac{d\phi}{dr} \approx \frac{6}{10} = 0.6\ \text{m s}^{-2}$$

$$\text{w.d.} = Fd$$

$$= (mg)d$$

$$= (2)(0.6)(2.5) = 3.0\ \text{J}$$

11 consider distance from Earth's centre

$$v = r\omega = \left(R_E + h\right)\omega$$

$$= \left(36000\times10^3 + 6400\times10^3\right)\left(\frac{2\pi}{24\times60\times60}\right)$$

$$= 3100\ \text{m s}^{-1}$$

12 assume ideal behaviour:

$$pV = nRT$$

$$T = \frac{pV}{nR} = \frac{(1\times10^5)(10\times3\times4)}{(5000)(8.31)}$$

$$= 289 \text{ K}$$

$$\frac{1}{\cancel{2}}mv_{rms}^2 = \frac{3}{\cancel{2}}kT$$

$$v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38\times10^{-23})(289)}{\frac{29\times10^{-3}}{N_A}}}$$

$$= 500 \text{ m s}^{-1}$$

Notes: need to change molar mass into SI units of kg.

13 thermal energy supplied goes to (i) heat liquid water up to 100 °C then (ii) boil

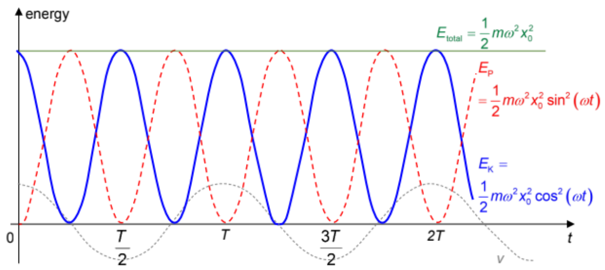
$$Q = mc\Delta T + mL_{vap} = m(c\Delta T + L_{vap})$$

$$= (5.00)\left[(4190)(100-30) + (2260\times10^3)\right]$$

$$= 1.28\times10^7 \text{ J}$$

14 the macroscopic "external" KE/PE does not affect internal energy (unchanged)

15 At max PE, KE = 0.
At max KE, PE = 0.
in simple(r) systems, by conservation of energy, PE + KE = constant total E



16 this works for laser light because the beam is coherent

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{3\times10^8}{5\times10^{14}}$$

$$= 6\times10^{-7} \text{ m}$$

$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$$

$$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} = 2\pi\frac{1.5\times10^{-6}}{6\times10^{-7}}$$

$$= 5.0\pi \text{ rad}$$

$$= 1.0\pi \text{ rad}$$

17 Malus Law for Intensity:

$$I = I_0\cos^2\theta$$

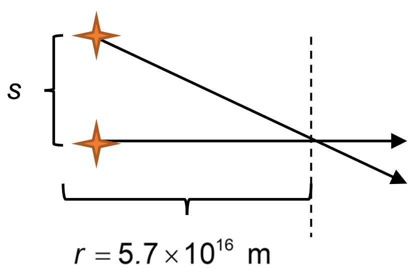
where θ is relative angle

X polarises incoming light vertically (0°)

From 45° to 90°, output intensity after rotated polarizer and before Y decreases to zero, because angle between X and rotated polarizer are 90° to each other: (**B**)

From 90° to 135°, output intensity after Y decreases to zero, because angle between rotated polarizer and Y are 90° to each other: (**B**)

18 sketch:



$$\frac{s}{r} \approx \frac{\lambda}{b}$$

$$s \approx r\frac{\lambda}{b} = (5.7\times10^{16})\frac{620\times10^{-9}}{0.5}$$

$$= 7.1\times10^{10} \text{ m}$$

19 recall definition of electric field line.

20 take ratio:

$$F_{\text{old}} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

$$\frac{F_{\text{new}}}{F_{\text{old}}} = \frac{Q_3 \cancel{Q_2}}{Q_1 \cancel{Q_2}}\left(\frac{r_{\text{old}}}{r_{\text{new}}}\right)^2$$

$$F_{\text{new}} = F_{\text{old}}\left(\frac{Q_3}{Q_1}\right)\left(\frac{r_{\text{old}}}{r_{\text{new}}}\right)^2$$

$$= (2.0)\left(\frac{2}{1}\right)\left(\frac{1}{2}\right)^2 = 1.0\text{ N}$$

21 Identify quantity related to gradient G:

$$R = \left(\frac{\rho}{A}\right)l$$

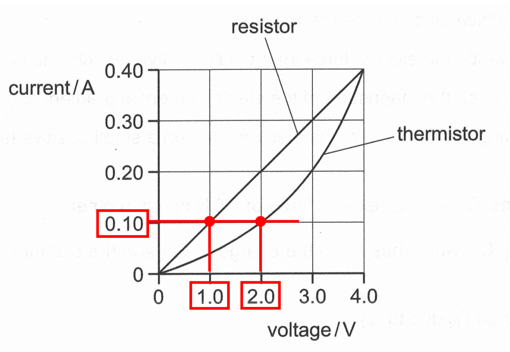
gradient $G = \dfrac{\rho}{A}$

4 wires are parallel (current “splits up” and rejoins”) so effective resistance is 1/4 original

$$R_{\text{eff}} = \frac{R}{4} = \frac{Gl}{4}$$

22 thermistor and resistor have same current flowing through them

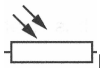
At current = 0.1 A, total p.d. across them is 3.0 V, equal to emf of battery.



23 $P = \dfrac{V^2}{R}$

for bulb to glow more, the p.d. across it must increase, then the effective resistance between it and the variable resistor in parallel must increase

by potential divider concepts,

> LDR  must be brighter to decrease its resistance

> thermistor must be cooler to increase its resistance and consequentially the resistance of the parallel branch comprising bulb and thermistor

24 By Right Hand Grip Rule on circular coil, *B* points out into plane of paper

by FLHR, upwards force on short wire

25 units of *BA* = T m^2

26 by faraday’s law

$$E = -\frac{\mathrm{d}}{\mathrm{d}t}N\Phi$$

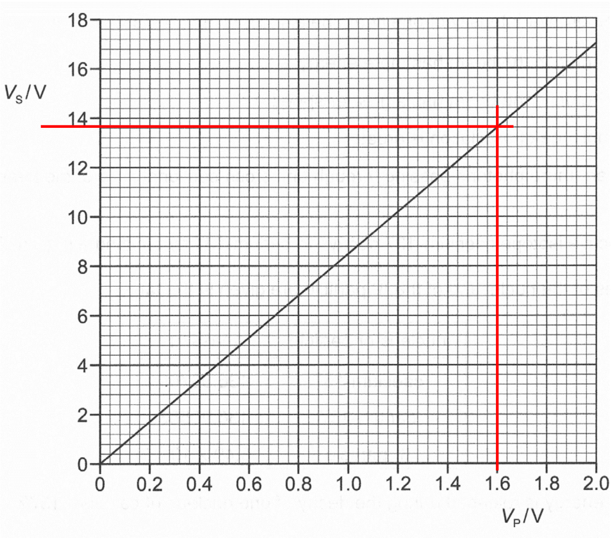
$$\approx -\frac{\Delta NBA}{\Delta t} = -N\frac{0 - BA}{\Delta t}$$

$$= N\frac{B\left(\pi r^2\right)}{\Delta t}$$

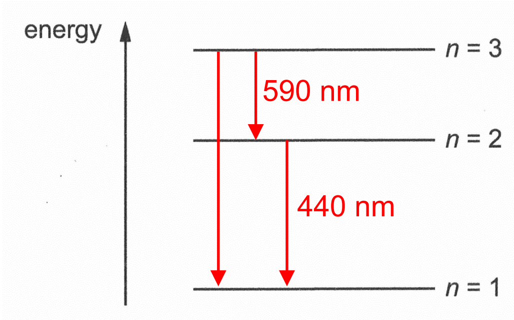
$$= (3000)\frac{(1.8)\left[\pi(0.01)^2\right]}{0.6} = 28\text{ V}$$

27 ideal so no loss of energy

$$P_{pri} = P_{sec}$$
$$I_{pri}V_{pri} = I_{sec}V_{sec}$$
$$I_{sec} = I_{pri}\left(\frac{V_{pri}}{V_{sec}}\right)$$
$$= (0.32)\left(\frac{1.6}{13.6}\right)$$



28 visualise the 3 possible transitions. longer wavelength is lower in energy:



$$E_{3\to1} = E_{2\to1} + E_{3\to2}$$
$$\frac{\cancel{hc}}{\lambda} = \frac{\cancel{hc}}{\lambda_{440\text{ nm}}} + \frac{\cancel{hc}}{\lambda_{590\text{ nm}}}$$
$$\lambda = \left[\frac{1}{440\times10^{-9}} + \frac{1}{590\times10^{-9}}\right]^{-1}$$
$$= 250\text{ nm}$$

29

$$I = \frac{P}{A} = \frac{nhf}{tA}$$
$$I = \left(\frac{hf}{A}\right)\frac{n}{t}$$

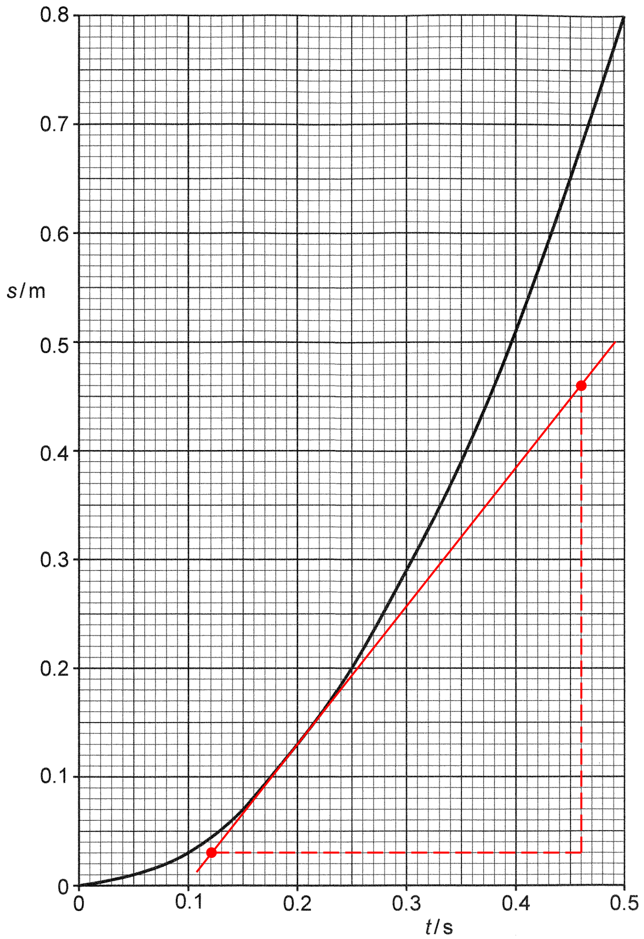
30 working with mass:

$$E = \left(m_{rxtnt} - m_{pdt}\right)c^2$$
$$= \left(m_{Ca} - m_{Ba} - m_{\beta}\right)uc^2$$
$$= 1.1\times10^{-13}\text{ J}$$

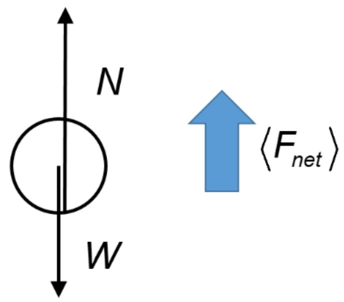
Paper 2
Structured Questions

General Notes: markers noted that higher quality responses (i) did not miss out on related elaborations, (ii) reflected common sensical logic checks e.g. whether the gravitational field strength in Q4 was of a reasonable value and (iii) demonstrated good presentation.

In the same year, markers of the H3 paper commented that strong presentation meant (i) writing out working clearly, (ii) manipulating equations via algebraic quantities for as long as reasonable and (iii) being sensitive towards s.f. considerations.

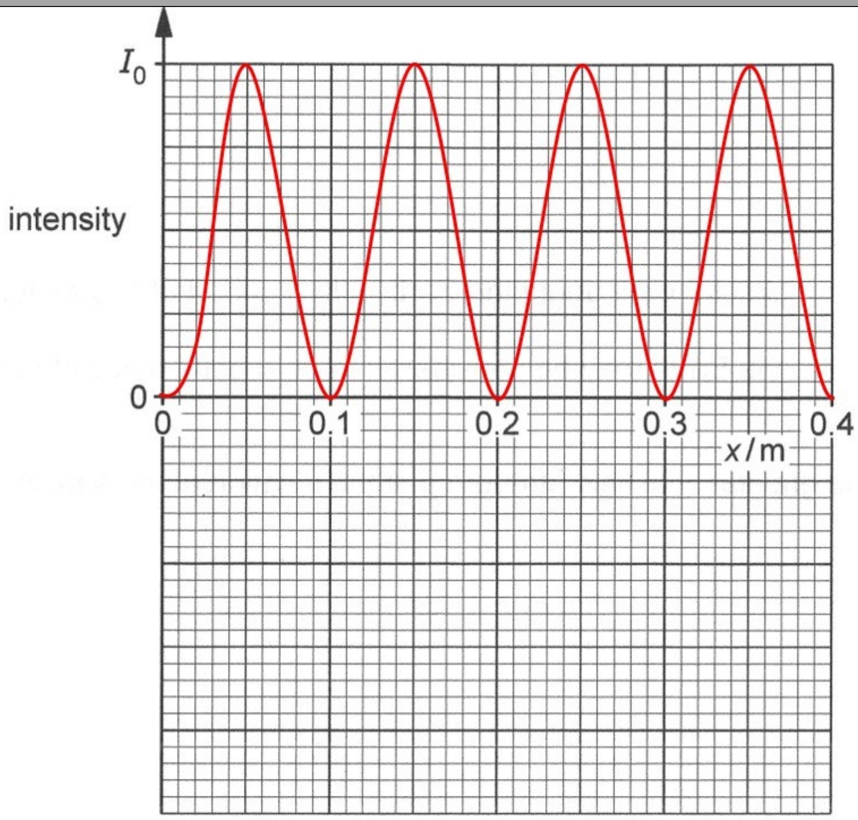
Qns		Marks
1(a)	[dxn] moves downslope [magnitude] with speed that increases at a constant rate	B1
1(b)(i)	gradient of displacement-time graphs gives velocity  $\lvert\text{velocity}\rvert \approx \dfrac{s_1 - s_2}{t_1 - t_2}$ $\approx \dfrac{0.03 - 0.46}{0.12 - 0.46}$ $= 1.26 \text{ m s}^{-1}$	B1 B1

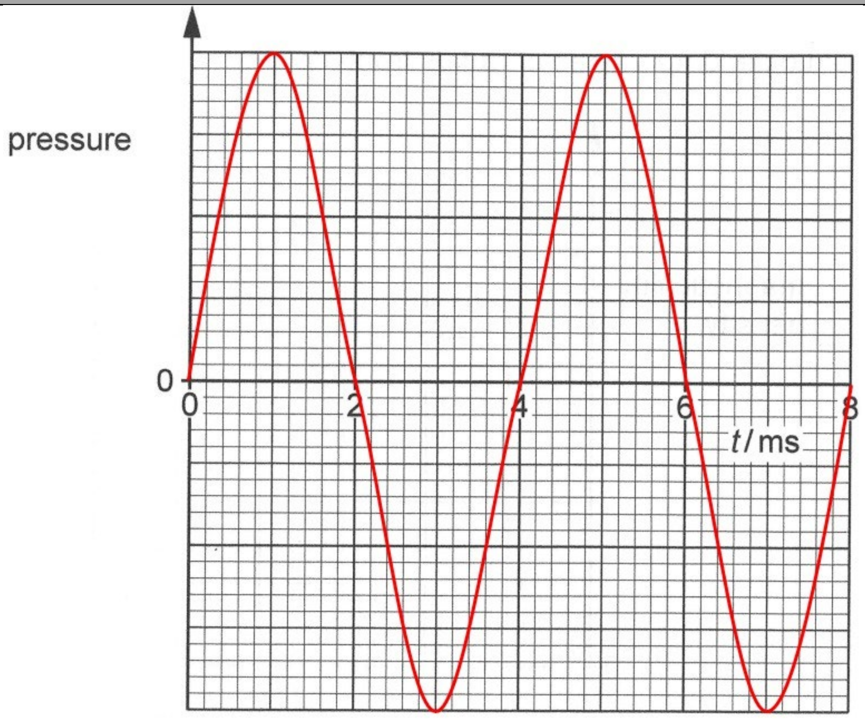
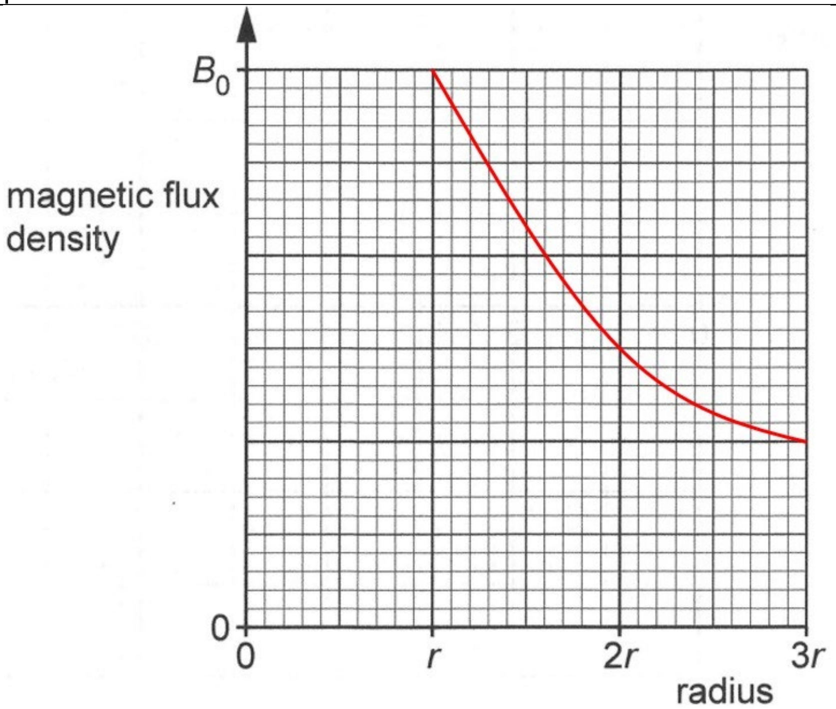
Qns		Marks
1(b)(ii)	$v^2 = u^2 + 2as$ $1.26^2 = 0 + 2a \times 0.130$ $a = 6.15 \text{ m s}^{-2}$ OR $v = u + at$ $1.26 = 0 + 0.200a$ $a = \dfrac{1.25}{0.200} = 6.32 \text{ m s}^{-2}$ **Note**: The formula is chosen such that *v* calculated in the previous part is used, as required by question.	M1 A1

Qns		Marks
2(a)	$KE = \dfrac{p^2}{2m}$ $= \dfrac{3.20^2}{2(0.62)}$ $= 8.26\ \text{J}$	C1 C1 A1
2(b)	Taking downwards as positive, $\Delta p = p_f - p_i$ $= -1.80 - 3.20$ $= -5.00\ \text{N s}$ $\Delta t = 0.68 - 0.53$ $= 0.15\ \text{s}$ By N2L: $\langle F_{\text{net}} \rangle = \dfrac{\Delta p}{\Delta t} = \dfrac{-5.00}{0.15} = -33.3\ \text{N}$  $\lvert \langle F_{\text{net}} \rangle \rvert = N - W$ $N = 33.3 + 0.62(9.81)$ $= 39.4\ \text{N}$ Average force will be 39.4 N, upwards. **Note**: commonly made error was missing out on change in direction	 C1 C1 M1 A1
2(c)	$KE \text{ upon bouncing} = \dfrac{p^2}{2m}$ $= \dfrac{(-1.8)^2}{2(0.62)}$ $= 2.61\ \text{J}$ $\text{Fraction of energy left after each bounce} = \dfrac{(2.61)}{(8.26)} = 0.316$ Let n be the number of bounces: $(0.316)^n E_0 \le 0.05E_0$ $n \ge 2.6$ $n = 3$ **Note**: don't leave out first bounce	 M1 M1 A1

Qns		Marks
3(a)	By Principle of Moments, take moments about Q, sum of clockwise moments = sum of anticlockwise moments $F\left(\frac{2}{3}\text{PQ}\right)\sin(43°) = W\left(\frac{1}{2}\text{PQ}\right)\cos(58°)$ $F\left(\frac{2}{3}\text{PQ}\right)\sin(43°) = (2.3)(9.81)\left(\frac{1}{2}\text{PQ}\right)\cos(58°)$ $F = 13.1\text{ N}$ **Note**: resolving forces *F* and *W* may be challenging	C1 C1 A1
3(b)	sign is in equilibrium, sum of all forces acting on the sign must be zero. [horizontal] force *F* has horizontal component acting on PQ to the right, so there must exist a horizontal force acting to the left by surface at Q. [vertical] there exists some upwards force at Q which adds to the upward component of force *F* to result in an upwards force of same magnitude as weight of PQ acting downwards vector addition of forces at Q is not vertical but is angled to the left. **Note**: this is the last part in a question, the intent is likely to differentiate the strong candidates and hence answers may need to be more elaborated. In particular, markers noted that stopping the discussion at just the horizontal components was insufficient.	B1 B1

Qns		Marks
4(a)	Using Newton's Law of Gravitation, $$F_G = \frac{GMm}{r^2}$$ As gravitational field strength is defined as gravitational force per unit mass placed at that point, $$g = \frac{F_G}{m} = \frac{\left(\frac{GM\cancel{m}}{r^2}\right)}{\cancel{m}} = \frac{GM}{r^2}$$ **Note**: whole derivation starting from Newton's Law of Gravitation is needed.	B1
4(b)	gravitational force provides centripetal force $$G\frac{M\cancel{m}}{r^2} = \cancel{m}r\omega^2$$ $$GM = r^3\left(\frac{2\pi}{T}\right)^2$$ $$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = 7.61\times10^6 \text{ m}$$ $$g = \frac{GM}{r^2} = \frac{(6.67\times10^{-11})(6.0\times10^{24})}{(7.61\times10^6)^2}$$ $$= 6.90 \text{ N kg}^{-1}$$	B1 C1 C1 A1
4(c)	acceleration = *net force / mass,* field strength = *gravitational force / mass*, gravitational force is the net force **Note**: markers are looking out for the linkage between definition of *g* and what is meant by "acceleration of free fall".	B1 B1 B1

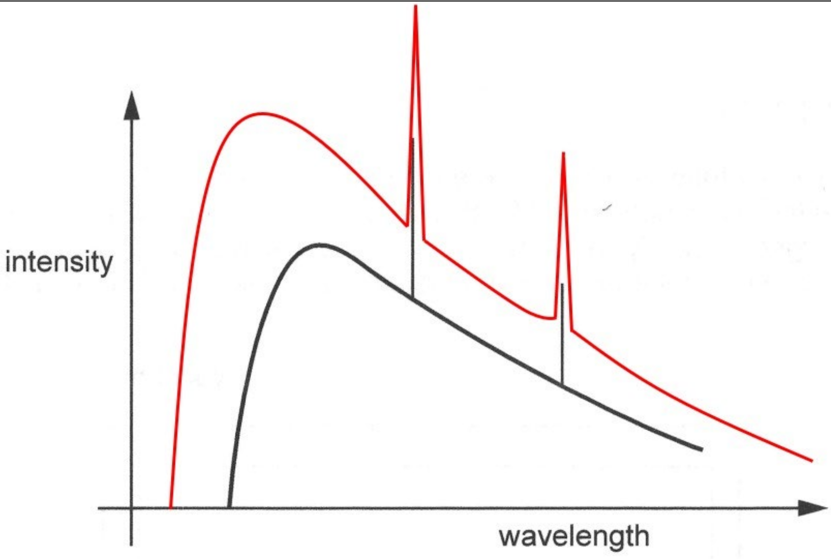
Qns		Marks
5(a)	 $\lambda_{\text{original wave}} = \frac{v}{f} = \frac{340}{1700} = 0.2$ distance between adjacent nodes or adjacent anti-notes is half-wavelength 0 intensity at 0.0 m, 0.1 m, 0.2 m, 0.3 m, 0.4 m. Max intensity at 0.05 m, 0.15 m, 0.25 m, 0.35 m. Sine-squared curve **Note**: shape of sine-squared curve needs to be correct. Intensity logically cannot be negative.	 B1 B1 B1

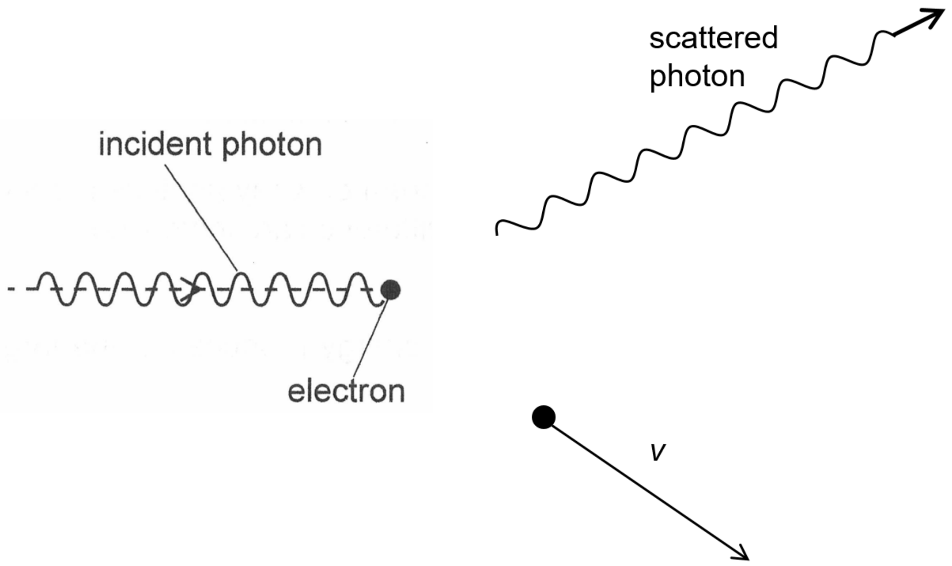
Qns		Marks
5(b)	 sinusoidal graph period = 4 ms	B1 B1
5(c)	 for flat circular coil, $B=\left(\frac{\mu_0 NI}{2}\right)\frac{1}{r}$ so shape follows $y=\frac{k}{x}$ shape [general shape] curve concaves upwards [accuracy of relationship] graph cuts through points (r,B_0), (2r,0.5B_0) and (3r,0.33B_0) [1 mark if only cuts through 2 of them]	B1 B2

Qns		Marks
6(a)(i)	$V_{lamp} = IR = (0.30)(5.0) = 1.5$ V p.d. across 3.0 $\Omega = 6.0 - 1.5 = 4.5$ V current in 3.0 $\Omega = \dfrac{4.5}{3.0} = 1.5$ A $I_R = 1.5 - 0.3 = 1.2$ A $R = \dfrac{V_R}{I_R} = \dfrac{1.5}{1.2} = 1.25\ \Omega$	M1 M1 A1
6(a)(ii)	$P = IV$ $\dfrac{P_{lamp}}{P_{supply}} = \dfrac{I_{lamp}V_{lamp}}{I_{emf}\,(\text{e.m.f})} = \dfrac{(0.3)(1.5)}{(1.5)(6.0)}$ take same ratio : $E_{lamp} = \dfrac{(0.3)(1.5)}{(1.5)(6.0)}(120) = 6.0$ J	 M1 M1 A1
6(a)(iii)	When first switched on, filament is cool and resistance of filament was minimum. for the same p.d. applied across filament, current is greatest initially as resistance of filament increases with temperature, continued operation increases resistance and results in decreasing current **Note**: when answering physics, state the changes e.g. before and after, initially and later, from what type of energy to what other type of energy etc. in this case, need to discuss what causes current to decrease after initial switch-on	B1 B1
6(b)	wires are connected in series, $I_X = I_Y$. $\dfrac{I_Y}{I_X} = \dfrac{n_Y A_Y v_{d,Y} q}{n_X A_X v_{d,X} q}$ $1 = \left(\dfrac{n_Y}{n_X}\right)\left(\dfrac{\cancel{\pi} r_Y^2}{\cancel{\pi} r_X^2}\right)\left(\dfrac{v_{d,Y}}{v_{d,X}}\right)$ $= \left(\dfrac{n_Y}{n_X}\right)(2)^2\left(\dfrac{1}{3}\right)$ $= \left(\dfrac{n_Y}{n_X}\right)\left(\dfrac{4}{3}\right)$ $\left(\dfrac{n_Y}{n_X}\right) = 0.75$	M1 M1 A1

Qns		Marks
7(a)	Charge distribution a very small proportion of positively-charged alpha particles (about 1 out of 8000) deflected more than 90°	B1
	suggests that nucleus is positively-charged but only exerts significant electrostatic repulsion on alpha particles that pass near nucleus	B1
	Mass distribution	
	majority of alpha particles passes through undeflected because they were sufficiently far enough from nucleus and experienced negligible electrostatic repulsion	B1
	most of atom is empty space and volume occupied by nucleus is very small compared to volume of atom	B1
7(b)	by principle of conservation of energy, at closest approach, initial KE of an alpha particle totally converted into electric PE between alpha and nucleus	C1
	$\left(5.59\times10^{6}\right)e=\frac{Q_{\alpha}Q_{\text{nucleus}}}{4\pi\varepsilon_0 r}$	C1
	$r=\frac{Q_{\alpha}Q_{\text{nucleus}}}{4\pi\varepsilon_0\left(5.59\times10^{6}\right)e}$ $=\frac{(2e)(79\cancel{e})}{4\pi\varepsilon_0\left(5.59\times10^{6}\right)\cancel{e}}=\frac{79\left(1.6\times10^{-19}\right)}{2\cancel{\pi}\left(5.59\times10^{6}\right)\left(\frac{1}{36\cancel{\pi}}\times10^{-9}\right)}$ $=4.07\times10^{-14}$ m	A1

Qns		Marks
7(c)	${}^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\alpha$	C1
	$\begin{pmatrix}\text{energy}\\ \text{released}\end{pmatrix} = \begin{pmatrix}\text{binding energy}\\ \text{of products}\end{pmatrix} - \begin{pmatrix}\text{binding energy}\\ \text{of reactants}\end{pmatrix}$	
	$= 218\begin{pmatrix}\text{BE per nucleon}\\ \text{of Po}\end{pmatrix} + 4\begin{pmatrix}\text{BE per nucleon}\\ \text{of alpha}\end{pmatrix} - 222\begin{pmatrix}\text{BE per nucleon}\\ \text{of Rn}\end{pmatrix}$	M1
	$\begin{pmatrix}\text{BE per nucleon}\\ \text{of Po}\end{pmatrix} = \frac{1}{218}\left(\begin{pmatrix}\text{energy}\\ \text{released}\end{pmatrix} - 4\begin{pmatrix}\text{BE per nucleon}\\ \text{of alpha}\end{pmatrix} + 222\begin{pmatrix}\text{BE per nucleon}\\ \text{of Rn}\end{pmatrix}\right)$	M1
	$= \frac{1}{218}\left(6.62 - 4(7.08) + 222(7.69)\right)$	
	$= 7.73\text{ MeV}$	A1

Qns		Marks
8(a)	accelerated electrons do not lose energy from colliding with air particles	B1
8(b)	 shorter minimum wavelength higher intensity position of characteristic peaks remain the same	 B1 B1 B1
8(c)(i)	$E_{\text{total}} = Q\Delta V$ $= (It)\Delta V$ thermal energy $= (0.99)(It)\Delta V$ $= (0.99)((0.12)(1.1))(65 \times 10^3)$ $= 8490$ J	C1 A1
8(c)(ii)	$Q = mc\Delta T$ $\Delta T = \dfrac{Q}{mc}$ $= \dfrac{8490}{(12 \times 10^{-3})(130)}$ $= 5440$ K	C1 A1
8(c)(iii)	To prevent melting/ overheating of any one part of the tungsten target at any time as a rise of 5440 K will cause temperature to be higher than melting point of tungsten	B1

Qns		Marks
8(d)(i)	 [vertical] opposite in direction [horizontal] both to the right	B1 B1
8(d)(ii)	some energy of photon transferred to electron and so scattered photon has less energy, correspondingly longer wavelength.	A0 M1
8(d)(iii)	[magnitude] image has <u>poorer contrast</u> between regions of high X-ray exposure and attenuated X-ray due to Compton scattering [direction] image looks out of focus / blur because transmitted X-ray photons scattered and so deviates from original path of incident X-ray photon	B1 B1
8(e)	attenuation = kZ^3 where k is a proportionality constant $\dfrac{\text{attenuation of X-rays in bone}}{\text{attenuation of X-rays in soft tissue}} = \dfrac{k(14)^3}{k(7)^3} = 8$	A1
8(f)	let intensity be I and initial maximum intensity be I_0 at $x_{1/2}$, $I = 0.5\ I_0$ $I = I_0 e^{-\mu x}$ $\dfrac{I}{I_0} = 0.5 = e^{-\mu x_{1/2}}$ $-\ln 2 = -\mu x_{1/2}$ $x_{1/2} = \dfrac{\ln 2}{\mu}$	M1 A1
8(g)	X-ray photons are highly energetic and is <u>ionizing radiation</u>, which can result in tissue damage at a cellular level. patient receives <u>less dosage</u> of X-rays with a more sensitive detector	B1

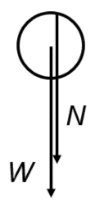
Qns		Marks
8(h)	digestive system is made of soft tissue similar to other parts of the body in the same abdominal region. will exhibit similar attenuation of X-rays in the region, results in lack of contrast around digestive system. Barium has a high *Z* number of 56 compared to the soft tissue and bones. Presence of barium in digestive system results in high attenuation of X-rays, and gives difference in X-ray intensity reaching detector, allowing digestive system to be contrasted in the image.	B1 B1
8(i)	Longer and more exposure to X ray doses per procedure for CT scan as more ‘images’ needs to be taken to form the 3D image. OR Image may not be that clear as more exposure means intensity of X-ray used per image needs to be lowered to prevent overdosing.	B1 B1 (B1) (B1)

Paper 3
Longer Structured Questions

General Notes: strong candidates were good with manipulating expressions before giving numerical answers. However, there was widespread demonstration of poorer manipulation skills in Q1(a)(i).

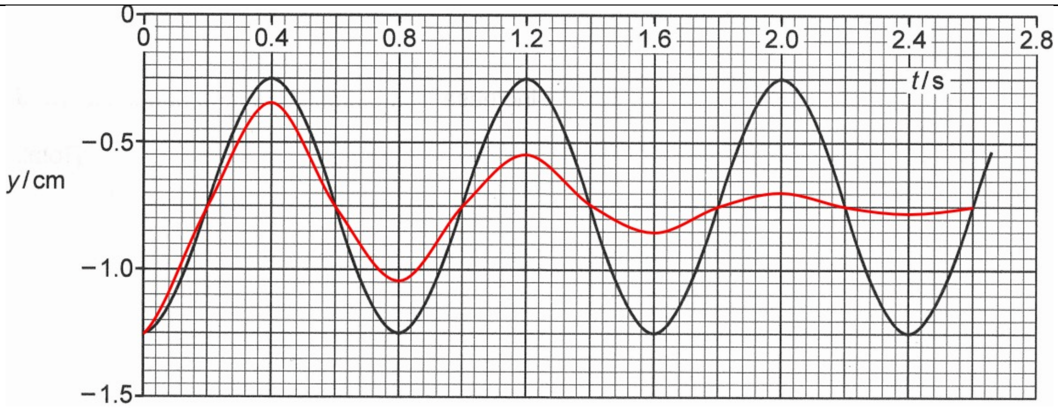
Candidates did not work well with drawing tangents, which occurred two times in this paper.

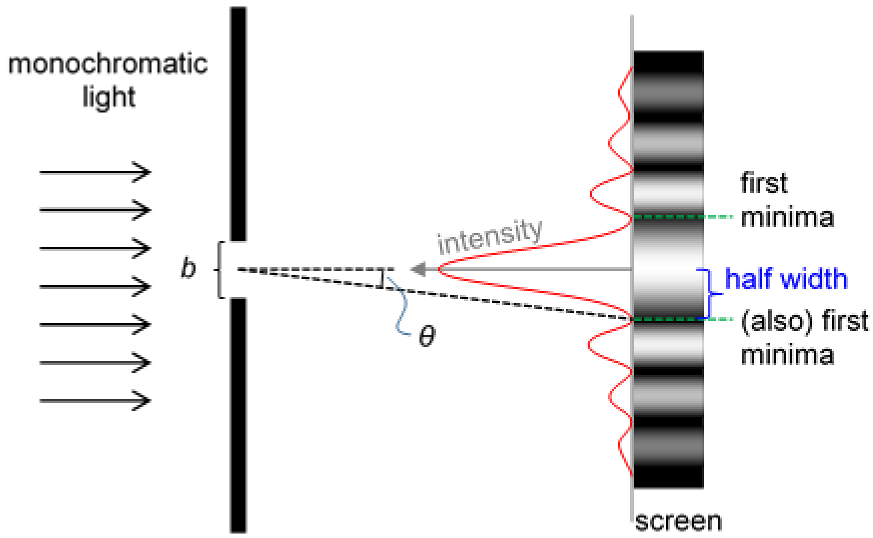
Candidates in general, were lacking in responding to explanation-type questions.

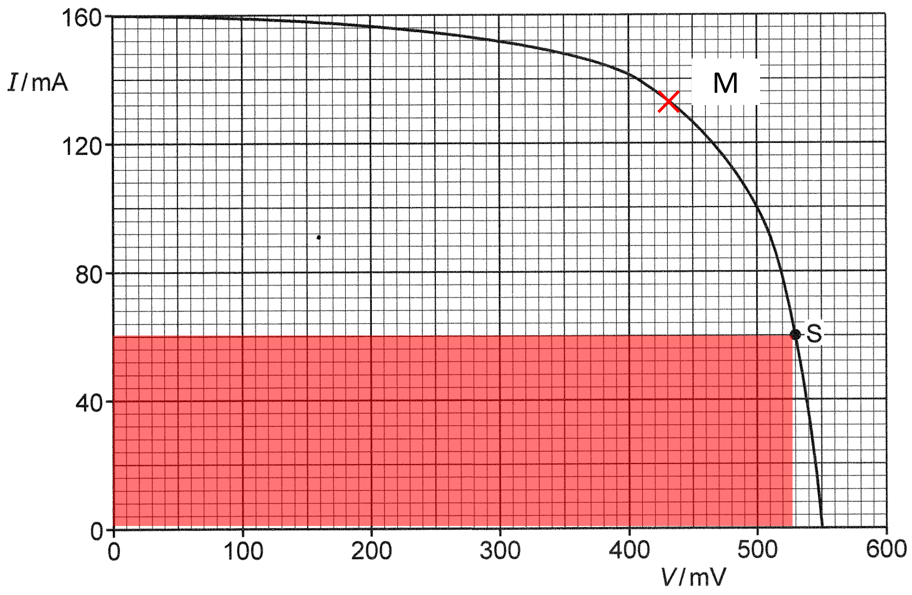
Qns		Marks
1(a)(i)	acceleration of ball down slope $= g \sin(\theta)$ $=(9.81) \sin(40°)$ $= 6.31$ m s^{-2} **Notes:** need to do a logic check that the acceleration does not exceed that of free fall. a useful technique is to consider logical extremes of the angle; acceleration should be zero when angle is zero.	 C1 A1
1(a)(ii)	$v^2 = u^2 + 2as$ $v^2 = (0)^2 + 2(6.31)(0.56)$ $v = 2.66$ m s^{-1} **Notes:** question stated to use the answer in (a)(i). Therefore, no credits for other methods such as conservation of energy.	 M1 A1
1(b)(i)	$F = \dfrac{mv^2}{r}$ $= \dfrac{(0.072)(1.5)^2}{(0.24 \div 2)}$ $= 1.35\text{ N}$	 C1 A1
1(b)(ii)	net force from vector addition of normal contact force and weight provides centripetal force $F_c = W + N$ $N = F_c - W$ $= 1.35 - (0.072)(9.81)$ $= 0.644$ N, vertically downwards  	B1 C1 A1

Qns		Marks
2(a)	gravitational force is attractive gravitational potential at infinity is zero decrease in potential energy as masses approach (or displacement and force in opposite directions)	B1 B1 B1
2(b)(i)	$\phi = -\frac{GM}{r}$ $= -\frac{(6.67\times10^{-11})(6.2\times10^{23})}{(3.4\times10^{3}\times10^{3})}$ $= -1.22\times10^{7}\ \text{J kg}^{-1}$	 A1
2(b)(ii)	minimum total energy stone needs to possess to reach infinity = 0 J Total energy of stone = GPE + KE $= m\phi + \frac{1}{2}mv^{2}$ $= (2.8)(-1.22\times10^{7})+(0.5)(2.8)(3.8\times10^{3})^{2}$ $= -1.38\times10^{7}$ J Since total energy of stone is smaller than 0. The stone will return to the surface.	B1 C1 A1

Qns		Marks
3(a)	[definition of internal energy] sum of kinetic energy due to random motion of a distribution of particles and potential energies due to intermolecular forces between the particles. [apply specifically to ideal gas] in an ideal gas, no exert intermolecular forces between particles, internal energy solely the sum of kinetic energy due to random motion of the gas particles. **Notes:** some candidates mistakenly left out the idea of "sum"	B1 B1
3(b)(i)	$pV = nRT$ $\frac{p}{nR} = \frac{V}{T} = \text{constant}$ $\frac{V_{\text{old}}}{T_{\text{old}}} = \frac{V_{\text{new}}}{T_{\text{new}}}$ $T_{\text{new}} = \frac{V_{\text{new}}}{V_{\text{old}}} T_{\text{old}} = \left(\frac{3.6}{3.2}\right)(273.15 + 12)$ $= 321 \text{ K} = 47.6 \text{ °C}$	C1 A1
3(b)(ii)	w.d. against atmosphere $=$ w.d. by gas $= -$w.d. on gas $= +p(V_{\text{final}} - V_{\text{final}})$ $= +(1.0 \times 10^5)((3.6 - 3.2) \times 10^{-3})$ $= +40 \text{ J}$	C1 A1
3(c)(i)	1st Law of thermodynamics, $\Delta U = Q_{\text{to}} + W_{\text{on}}$ $= 101 + (-40)$ $= +61 \text{ J}$	A1
3(c)(ii)	no microscopic PE in ideal gas so all increase in internal energy went into increase total microscopic KE avg increase in KE $= \frac{61}{N} = \frac{61}{\frac{pV}{kT}}$ $= 61\frac{(1.38 \times 10^{-23})(12 + 273.15)}{(1.0 \times 10^5)(3.2 \times 10^{-3})}$ $= 7.50 \times 10^{-22} \text{ J}$ **Notes:** not advisable to use $\frac{\Delta U}{N} = \frac{3}{2}k\Delta T$ because there is assumption of gas being monoatomic ideal gas which is not stated in the question.	C1 M1 A1

Qns		Marks
4(a)(i)	$x_0 = [-0.25 - (-1.25)] \div 2 = 0.50\ \text{cm}$ **Notes:** candidates who gave the answer as 0.5 cm were penalized for insufficient s.f./d.p..	A1
4(a)(ii)	$T = \frac{2.4}{3} = 0.8\ \text{s}$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{0.8} = 7.85\ \text{rad s}^{-1}$ **Notes:** idea of taking average across multiple oscillations needs to be demonstrated.	M1 A1
4(a)(iii)	$v = \pm\omega\sqrt{x_0^2 - x^2}$ $v_0 = (7.85)\sqrt{0.5^2 - 0.0^2}$ $= 3.93\ \text{cm s}^{-1}$	C1 A1
4(b)	 sinusoidal wave with decreasing amplitude start from same point at t = 0 period remains relatively constant (light damping)	B1 B1 B1

Qns		Marks
5(a)	spreading of a wave (into geometric shadow) when it passes **through a slit** or **around an edge** of an obstacle **Notes:** cannot be confused by gaps and obstacles, need to use proper language, e.g. a wave cannot pass *through* an obstacle	B1 B1
5(b)(i)	single slit diffraction: $\sin\theta = \frac{\lambda}{b} \approx \frac{\frac{1}{2}(\text{width})}{D}$ $\text{width} = \frac{2D\lambda}{b}$ $= \frac{2(2.6)(590\times10^{-9})}{0.100\times10^{-3}}$ $= 0.0307 \text{ m}$  	C1 C1 A1
5(b)(ii)	fringe separation due to double-slit: $x = \frac{\lambda D}{a}$ $= \frac{(590\times10^{-9})(2.6)}{0.100\times10^{-3}}$ number of fringes that can fit inside width of single-slit central fringe: $\frac{(\text{width})}{\left(\frac{\lambda D}{a}\right)} = \frac{a(\text{width})}{\lambda D} = \frac{a\left(\frac{2\cancel{D\lambda}}{b}\right)}{\cancel{\lambda D}} = \frac{2a}{b} = \frac{(2)(1.40)}{0.100} = 28$	 C1 C1 A1

Qns		Marks
6(a)(i)		

Qns		Marks
	rectangle shaded. correct region shaded.	B1 B1
6(a)(ii)	want largest area of rectangle; M is on graph with *V* between 420 mV to 440mV.	A1

V / mV	*I* / mA	*P* / μW
390	143	55770
400	142	56800
410	138	56580
420	136	57120
430	134	57620
440	130	57200
450	126	56700
460	122	56120
470	118	55460

6(b)(i)

$V = IR$,

$$R = \frac{V}{I} = \frac{500\times10^{-3}}{100\times10^{-3}} = 5.00\ \Omega$$

C1
A1

6(b)(ii)

$$P = IV = (100\times10^{-3})(500\times10^{-3})$$
$$= 0.0500\ \text{W}$$

C1
A1

6(b)(iii)

e.m.f. is 550 mV when current is zero — M1

$$V_{\text{terminal}} = \text{emf} - Ir$$

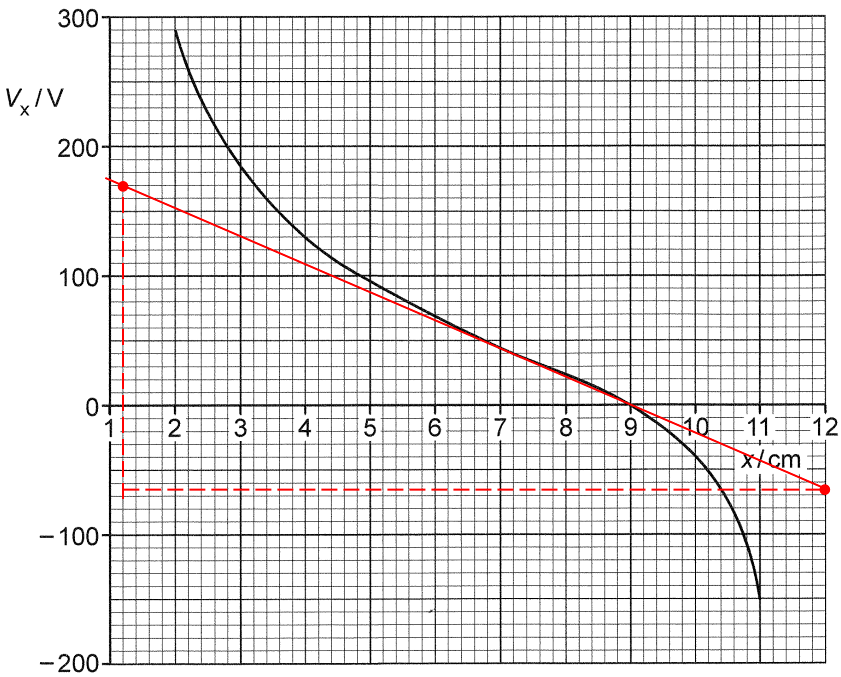
$$r = \frac{\text{emf} - V_{\text{terminal}}}{I}$$

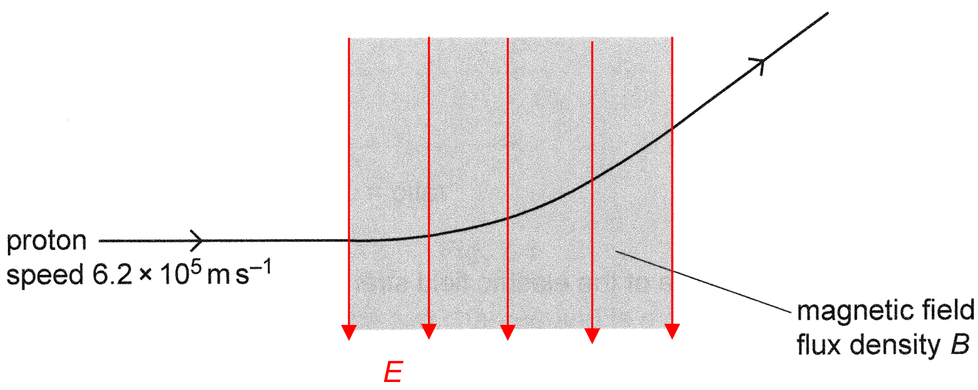
$$= \frac{(550-500)\times\cancel{10^{-3}}}{100\times\cancel{10^{-3}}}$$

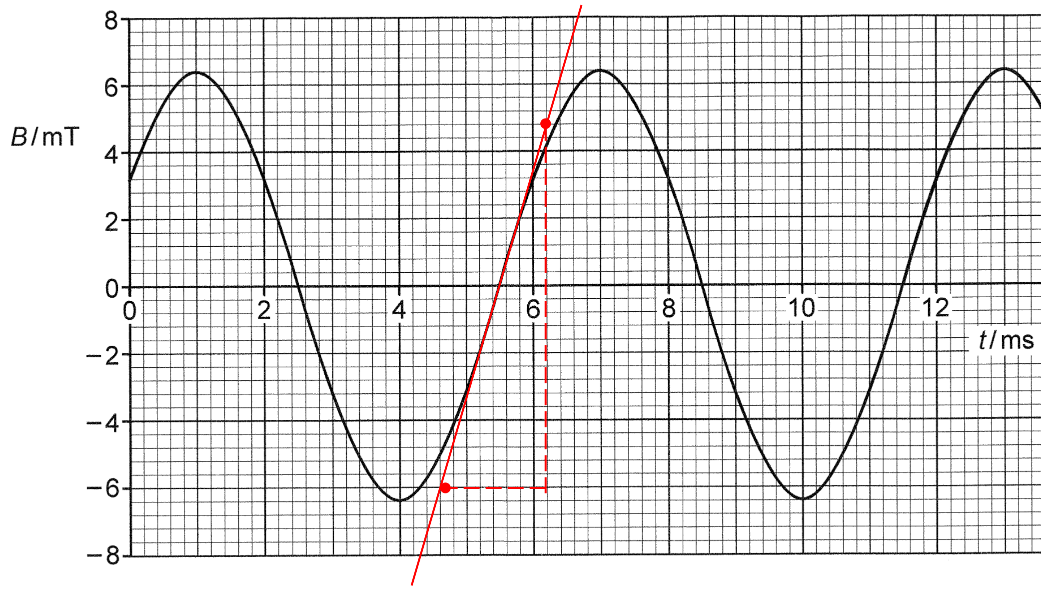
$$= 0.500\ \Omega$$

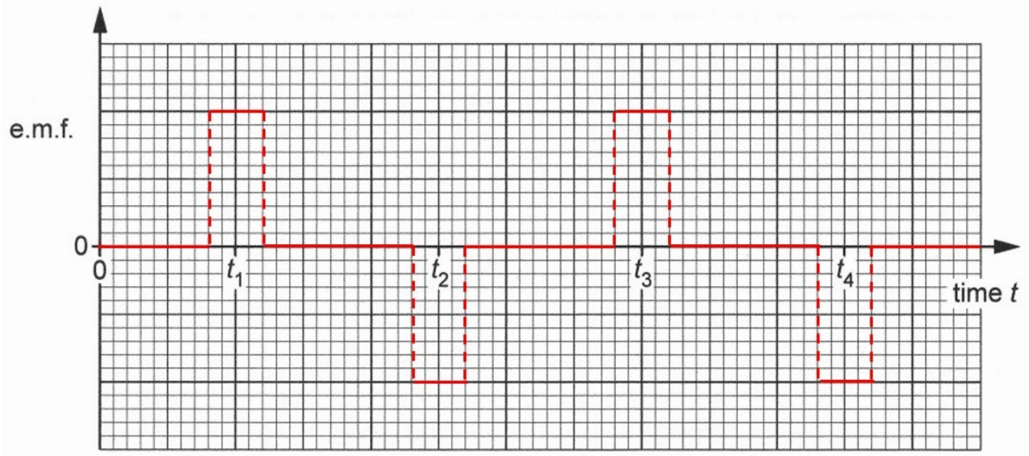
A1

Notes: cannot apply maximum power theorem here because it is not maximum power for current = 100 mA

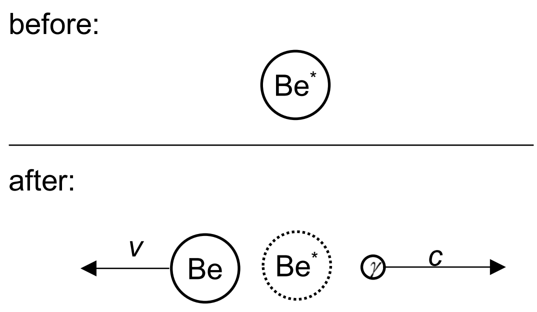
Qns		Marks
7(a)	similarity: Both potentials are inversely proportional to the distance from the source. difference: Electric potential can be either positive or negative but gravitational potential is always negative.	B1 B1
7(b)(i)	opposite charge as potential is positive when distance *x* is between 0 cm and 9 cm and is negative when x is more than 9 cm **Notes:** need to mention both positive and negative portions of the graph	B1
7(b)(ii)	$V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ at $x=9.0$, $V_{\text{resultant}}=0$ $\lvert V_A\rvert=\lvert V_B\rvert$ $\left(\cancel{\frac{1}{4\pi\varepsilon_0}}\right)\frac{Q_A}{9\times\cancel{10^{-2}}}=\left(\cancel{\frac{1}{4\pi\varepsilon_0}}\right)\frac{Q_B}{(12-9)\times\cancel{10^{-2}}}$ $\frac{Q_A}{Q_B}=\frac{9}{3}=3.0$	M1 M1 A1
7(b)(iii)	 electric field strength is numerically equal to potential gradient that point and acts in the direction of decreasing potential gradient $=\frac{y_1-y_2}{x_1-x_2}=\frac{170-(-65)}{(1.2-12)\times10^{-2}}=-2180$ $E=-\frac{dV}{dr}=2180\text{ N C}^{-1}$, towards B **Notes:** accepted range is $2100\pm100\text{ N C}^{-1}$	 C1 M1 A1

Qns		Marks
8(a)	Magnetic flux density *B* is the force acting per unit current per unit length on a wire carrying a current that is normal to the magnetic field. **Notes:** marks are lost if it is stated as "unit current" instead of "*per* unit current"	B1 B1 B1
8(b)(i)	magnetic force that provides centripetal force on proton is always normal to velocity no displacement in direction of force so no work done, therefore no change in kinetic energy of proton so speed remains constant proton trace out a path that is an arc of a circle.	B1 B1 A0
8(b)(ii)	magnetic force provides for centripetal force $F_B = F_C$ $Bq\cancel{v}\sin\theta = \dfrac{mv^{\cancel{2}}}{r}$ $B(1.60\times10^{-19})(6.2\times10^{5})\sin(90°) = \dfrac{(1.67\times10^{-27})(6.2\times10^{5})^2}{7.6\times10^{-2}}$ $B = \dfrac{mv}{qr\ (\sin\theta)} = \dfrac{(1.67\times10^{-27})(6.2\times10^{5})}{(1.6\times10^{-19})(7.6\times10^{-2})(\sin 90°)}$ $= 8.51\times10^{-2}$ T	M1 A1
8(c)(i)		
8(c)(ii)	For the proton to be undeviated, F_{net} = 0 N $\lvert F_E\rvert = \lvert F_B\rvert$ $\cancel{q}E = B\cancel{q}v$ $E = Bv = (8.51\times10^{-2})(6.2\times10^{5})$ $= 52800$ V m^{-1}	M1 A1
8(d)(i)	$B_{rms} = \dfrac{B_0}{\sqrt{2}} = \dfrac{6.4\times10^{-3}}{\sqrt{2}} = 4.53\times10^{-3}$ T	A1
8(d)(ii)	1 ms , 4 ms, 7 ms, 10 ms, 13 ms (any 2; one mark each)	B1 B1

Qns		Marks
8(e)	by faraday's law, $\lvert E\rvert = \left\lvert\frac{\mathrm{d}\Phi}{\mathrm{d}t}\right\rvert = NA\left\lvert\frac{\mathrm{d}B}{\mathrm{d}t}\right\rvert$ so max e.m.f. is induced at steepest gradient which corresponds to largest rate of change of magnetic flux $\frac{\mathrm{d}B}{\mathrm{d}t}$:	C1
		
	$\left.\frac{\mathrm{d}B}{\mathrm{d}t}\right\rvert_{max} = \frac{(4.8-(-6))\times \cancel{10^{-3}}}{(6.2-4.6)\times \cancel{10^{-3}}} = \frac{(4.8-(-6))}{(6.2-4.6)} = 6.75\ \mathrm{T\ s^{-1}}$	C1
	$\lvert E\rvert = NA\left\lvert\frac{\mathrm{d}B}{\mathrm{d}t}\right\rvert$	
	$\lvert E\rvert_{max} = N(\pi r^2)\left\lvert\frac{\mathrm{d}B}{\mathrm{d}t}\right\rvert_{max}$	C1
	$= (270)\pi\left(\frac{2.4\times 10^{-2}}{2}\right)^2 (6.75)$	
	$= 0.824\ \mathrm{V}$	A1

Qns		Marks
8(f)	 zero when flux is a horizontal line in Fig. 8.4. positive e.m.f. when gradient of graph in Fig. 8.4 is negative negative e.m.f. when gradient of graph in Fig. 8.4 is positive constant e.m.f. induced shown by horizontal line in Fig. 8.5	B1 B1 B1 B1

Qns		Marks
9(a)(i)1. **9(a)(i)2.**	Any 2 points from: (max) energy of emitted electrons depends on frequency (max) energy of emitted electrons does not depend on intensity rate of emission of electrons depends on intensity (at constant frequency) existence of frequency below which no emission of electrons instantaneous emission of electrons increasing the frequency at constant intensity decreases the rate of emission of electrons	B1 B1
9(a)(ii)	each coloured line corresponds to one wavelength/frequency energy = Planck constant × frequency each wavelength is associated with a discrete change in energy discrete energy change implies discrete levels	B1 B1 B1
9(b)(i)	$E = hf = \dfrac{hc}{\lambda}$ $= \dfrac{(6.63\times10^{-34})(3.00\times10^{8})}{340\times10^{-9}}$ $= 5.85\times10^{-19}$ J $= 3.66$ eV	C1 C1 A1
9(b)(ii)	Photon of purple light has the shortest wavelength and highest energy in the visible light spectrum. All possible de-excitations of electrons to the -13.6 eV energy level is already more energetic than photon of purple light of 3.66 eV. This will result in photons of more energy and therefore shorter wavelength; and the human eye is unable to see such ultraviolet or more energetic electromagnetic radiation.	B1 B1
9(c)(i)	probability of decay in 1 day is also known as decay constant $t_{1/2} = \dfrac{\ln 2}{\lambda}$ $\lambda = \dfrac{\ln 2}{53} = 1.31\times10^{-2}$ day^{-1}	A1

Qns		Marks
9(c)(ii)	$N_0 = \dfrac{m_{\text{total}}}{7u} = \dfrac{5.7\times10^{-12}}{7\left(1.66\times10^{-27}\right)}$ $= 4.91\times10^{14}$ $N = N_0 \exp\left(-\lambda t\right)$ $= \left(4.91\times10^{14}\right)\exp\left(-\left(1.31\times10^{-2}\right)120\right)$ $= 1.02\times10^{14}$	C1 C1 A1
9(c)(iii)	Gamma decay only involves the release of energy in the form of gamma photons from an excited nucleus, and does not involve the splitting or combining of the nuclei no change in the number of protons in the nucleus and no change in the number of nuclei.	B1 B1
9(d)	 by principle of conservation of momentum: $p_{\text{Be}} + p_\gamma = 0$ $\lvert p_{\text{Be}}\rvert = \lvert p_\gamma\rvert$ $mv = \dfrac{h}{\lambda}$ $(7u)v = \dfrac{hf}{c} = \dfrac{E}{c}$ $v = \dfrac{E}{7uc}$ $= \dfrac{\left(0.48\times10^{6}\right)\left(1.6\times10^{-19}\right)}{7\left(1.66\times10^{-27}\right)\left(3.00\times10^{8}\right)}$ $= 2.20\times10^{4}\ \text{m s}^{-1}$	C1 C1 C1 A1