PHYSICS

9749

SUGGESTED MARK SCHEME
Maximum Mark: 190

October/November 2022

Paper 1
Multiple Choice

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

1 Since vectors are initially in opposite directions, the initial ($X - Y$) yields the largest magnitude, eliminate **B** and **D**

180° means that Y is rotated half-round only, where magnitude of ($X - Y$) will not return to original value.

2 took 1 sec for vertical component of velocity to be zero

$$\vec{u} = \vec{u}_x + \vec{u}_y$$

$$\vec{u}_x(t) = s_x$$

$$\vec{u}_x = \frac{s_x}{t} = \frac{50}{1} = 50 \text{ m s}^{-1}$$

$$\vec{v}_y = \vec{u}_y + at$$

$$\vec{u}_y = \vec{v}_y - at = 0 - (-9.81)(1)$$

$$= 9.81 \text{ m s}^{-1}$$

$$\tan\theta = \frac{\vec{u}_y}{\vec{u}_x}$$

$$\theta = \tan^{-1}\left(\frac{9.81}{50}\right)$$

$$= 11.1°$$

3 by conservation of linear momentum

$$m_P(2)+0=m_p(-0.5)+m_Q v_Q$$
$$(2.5)m_P=m_Q v_Q \_\_\_\_\_\_ (1)$$

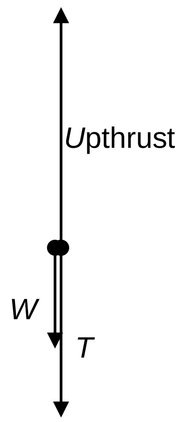
elastic so

$$v_Q-(-0.5)=2-0$$
$$v_Q=1.5\text{ m s}^{-1}$$

from (1):

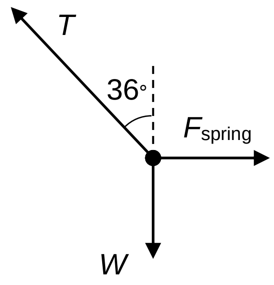
$$\frac{m_P}{m_Q}=\frac{v_Q}{2.5}=\frac{3}{5}$$

4 consider free body diagram of buoy:



$$U=W+T$$
$$T=U-W=(\rho_{\text{water}}V_{\text{submerged}}g)-mg$$
$$=\left((1030)\left[\frac{1}{2}\left(\frac{4}{3}\pi(0.5)^3\right)\right]-200\right)(9.81)$$
$$=683\text{ N}$$

5 consider free body diagram of mass in translational equilibrium:



horizontally:

$$T\sin(36°)=kx=(25)(0.06)$$

vertically:

$$T\cos(36°)=W$$
$$W=\left(\frac{(25)(0.06)}{\sin(36°)}\right)\cos(36°)$$
$$=2.06\text{ N}$$

6 mean density so assume earth is uniform sphere:

$$|g|=\frac{GM}{r^2}$$
$$\frac{g}{\frac{4}{3}\pi r}=G\frac{M}{\frac{4}{3}\pi r^3}=G\rho$$
$$\rho=\frac{g}{\frac{4}{3}\pi rG}$$
$$=\frac{9.81}{\frac{4}{3}\pi(6.37\times10^6)(6.67\times10^{-11})}$$
$$=5512\text{ kg m}^{-3}$$

7 by conservation of energy, loss of GPE = work done against air resistance:

$$n=2$$
$$\text{loss in GPE}=mg(h_0-h_2)$$
$$=mg(0.6-0.6e^{-0.2})$$
$$=(0.4)(9.81)(0.6)[1-e^{-0.2}]$$
$$=0.427\text{ J}$$

8 all points along a radius have the same angular speed (the *linear* speed of the point on the circumference is the max and the linear speed at the centre is zero)

9 Eliminate **A** and **B** as all geostationary satellites, regardless of their mass, has to be at a fixed distance away from centre of Earth

Eliminate **D**, the satellite will have the same angular velocity as the point on Earth's surface directly below them but the satellite will have far more linear velocity (see reasoning in Q8)

10 gravitational potential is a scalar sum so:

$$\phi_P = \phi_{\text{due to M}} + \phi_{\text{due to 4M}}$$
$$= \left(-\frac{GM}{\frac{d}{2}}\right) + \left(-\frac{G(4M)}{\frac{d}{2}}\right)$$
$$= \frac{-2GM}{d}[1+4] = \frac{-10GM}{d}$$

11 ideal gas so internal energy is purely KE and is directly proportional to thermodynamic temperature:

$$\frac{KE_{\text{new}}}{KE_{\text{old}}} = \frac{T_{\text{new}}}{T_{\text{old}}}$$
$$\frac{c_{\text{new}}^2}{c_{\text{old}}^2} = \frac{T_{\text{new}}}{T_{\text{old}}}$$
$$c_{\text{new}} = c_{\text{old}}\sqrt{\frac{T_{\text{new}}}{T_{\text{old}}}}$$
$$= (350)\sqrt{\frac{160+273.15}{80+273.15}}$$
$$= 388 \text{ m s}^{-1}$$

12 ideal gas so internal energy is purely KE and is directly proportional to thermodynamic temperature. Since temperature remains constant, total KE of both initial or final states is same.

$$p = \frac{1}{3}\frac{Nm}{V}c^2$$
$$\frac{3}{2}pV = \frac{1}{2}Nmc^2 = KE_{\text{total}}$$
$$= \frac{3}{2}(10^5)(0.01)$$
$$= 1500 \text{ J}$$

13 half of KE converted into thermal energy

$$\frac{1}{2}\left(\frac{1}{2}\cancel{m}v^2\right) = \cancel{m}c\Delta T$$
$$\Delta T = \frac{v^2}{4c}$$

14 start with displacement equation and differentiate with respect to time

$$x = x_0\sin(\omega t)$$
$$= x_0\sin\left(\frac{2\pi}{T}t\right)$$
$$= (0.3)\sin\left(\frac{2\pi}{5}t\right)$$
$$v = \frac{dx}{dt}$$
$$= \frac{(0.3)(2\pi)}{5}\cos\left(\frac{2\pi}{5}t\right)$$
$$\approx (0.377)\cos(1.27t)$$

15 **A** because the radio need not be outputting sounds of (driving) frequency which matches that of the natural frequency of the loudspeaker

16 diagram 2 shows frequency

$$f = \frac{1}{T} = \frac{1}{0.2} = 5 \text{ Hz}$$

diagram 1 shows wavelength

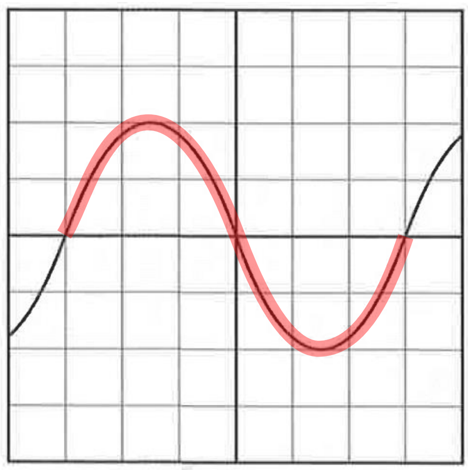
$\lambda = 0.8$ m

$$v = f\lambda = (5)(0.8) = 4 \text{ m s}^{-1}$$

17 stationary wave so XY represents half-wavelength

$\lambda = 2(5) = 10$ cm

eliminate **A** and **C**



6 divisions on time base gives 1 period

$$T = 6(0.05 \times 10^{-3})$$

$$f = \frac{1}{T} = \frac{1}{6(0.05 \times 10^{-3})}$$

$$= 3333 \text{ Hz}$$

18 double slit experiment so

$$x = \frac{\lambda D}{a} \rightarrow \frac{x}{15} = \frac{\lambda}{a}$$

$$x_A = \frac{700 \times 10^{-9}}{4 \times 10^{-3}} = 0.000175 \text{ m}$$

$$x_B = \frac{20}{50 \times 10^{-3}} = 400 \text{ m}$$

$$x_C = \frac{450 \times 10^{-9}}{2 \times 10^{-3}} = 0.000225 \text{ m}$$

$$x_D = \frac{10 \times 10^{-3}}{200 \times 10^{-3}} = 0.05 \text{ m}$$

19 approach question using kinematics

consider time of flight (time spent inside uniform field)

$$y = vt$$

$$t = \frac{y}{v} \quad \text{———} (1)$$

$$F = qE$$

$$ma = e\left(\frac{V}{d}\right)$$

$$a = \frac{eV}{md} \quad \text{———} (2)$$

$$s = ut + \frac{1}{2}at^2$$

$$x = 0 + \frac{1}{2}\left(\frac{eV}{md}\right)\left(\frac{y}{v}\right)^2$$

20 current along wire is constant so the larger the diameter, the lower the drift velocity, eliminate **C** and **D**

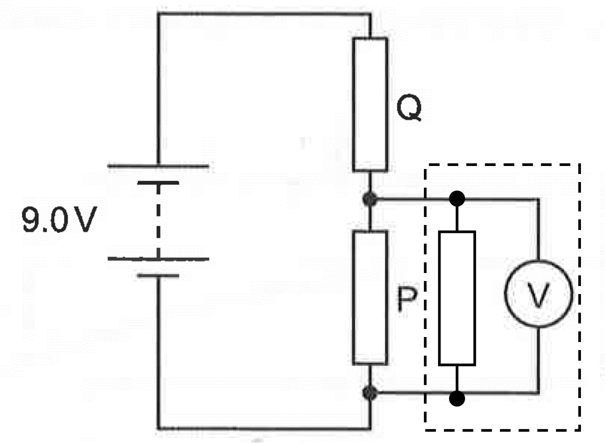
$$I = Anvq$$

$$= (\pi r^2)nve$$

$$= \left(\pi\left(\frac{d}{2}\right)^2\right)nve$$

$$v = \left(\frac{4}{ne\pi}\right)\frac{1}{d^2}$$

21 non-ideal voltmeter can be regarded as its resistance in parallel with an idea voltmeter



$$R_{//} = \frac{R_P}{2}$$

$$I = \frac{V_{//}}{R_{//}} = \frac{2V}{R_P} = \frac{12}{R_P}$$

$$I = \frac{V_Q}{R_Q}$$

$$\frac{12}{R_P} = \frac{3}{R_Q}$$

$$\frac{R_P}{R_Q} = \frac{12}{3} = 4$$

22 e.m.f. of call is 65 cm worth of p.d.

$$\text{e.m.f.} = \left(65 \times 10^{-2}\right)(14.3)$$
$$= 9.30 \text{ V}$$

23 the forces are N3L pairs, eliminate **B** & **D**

wires attract so current flowing in same direction

24 initially current is normal to B so max value expected with $\theta = 0$, eliminate **A** & **C**

$F = BIL\sin\theta$ so cannot be straight line

25 component of flux normal to area is $B_\perp = B\ \sin(60°)$

$$\Phi = B_\perp A = BA\ \sin(60°)$$
$$= \left(65 \times 10^{-6}\right)\left(12 \times 10^{-4}\right)\sin(60°)$$
$$= 6.75 \times 10^{-8} \text{ Wb}$$

26 regular square wave so $I_{rms} = I_0$

27 magnetic flux linkage in an a.c. generator is of the form

$$N\phi = NBA\ \sin(\omega t)$$

$$\frac{dN\phi}{dt} = NBA\omega\ \cos(\omega t)$$

peak e.m.f. is halved,

new $P = \frac{V^2}{R}$ is $\frac{1}{4}$ of original

original power:

$$P = I_{rms}^2 R$$
$$= \frac{I_0^2}{2} R$$
$$= \frac{4}{2}(20)$$
$$= 10 \text{ W}$$

28 electron has mass, consider:

$$E = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\frac{\lambda_{\text{new}}}{\lambda_{\text{old}}} = \sqrt{\frac{E_{\text{old}}}{E_{\text{new}}}}$$

$$\lambda_{\text{new}} = \lambda\sqrt{\frac{E}{9E}} = \frac{\lambda}{3}$$

29 mass defect is difference between total mass of individual separate nucleons and mass of nucleus

bismuth isotope has 83 protons and 129 neutrons

$$\Delta m = 83M_{\text{p}} + 129M_{\text{n}} - M$$

30 alpha decay reaction:

$$^{238}\text{U} \rightarrow {}^{234}\text{Th} + {}^{4}_{2}\alpha$$

energy released

$$= \left[\begin{pmatrix}\text{rest mass} \\ \text{of uranium}\end{pmatrix} - \begin{pmatrix}\text{rest mass} \\ \text{of products}\end{pmatrix}\right]c^2$$

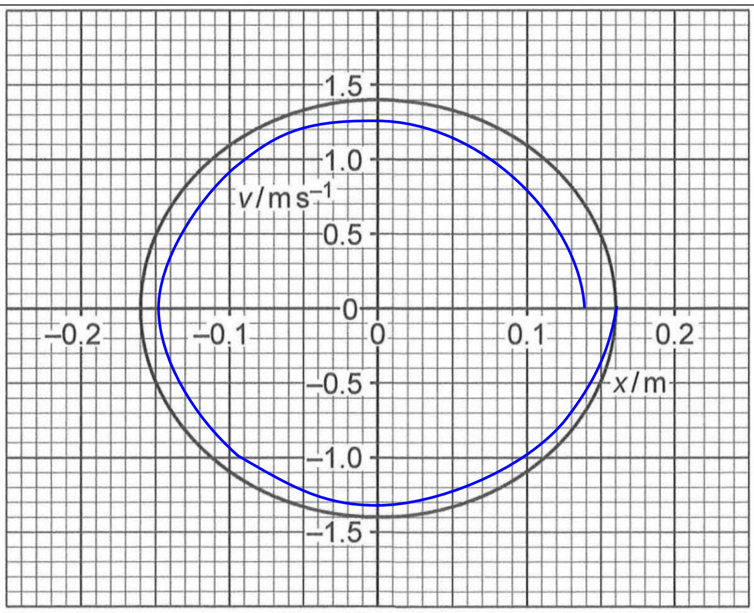
$$= (238.1249 - 234.1165 - 4.0026)uc^2$$

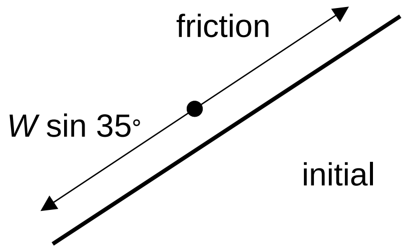
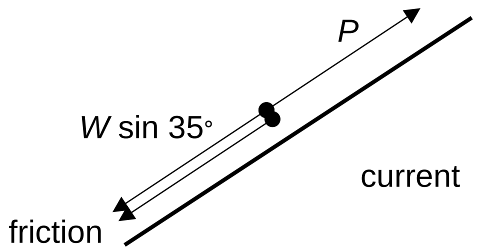
$$= 8.67 \times 10^{-13}\ \text{J}$$

Paper 2
Structured Questions

General Notes:
There was no evidence of candidates being unable to complete the paper in the time available.
Some responses were not relevant to the question asked. In **Question 3(a)**, some candidates introduced a magnetic field that was not in the question.
Weaker responses did not take care with the use of terms and ideas in physics. Some candidates conflated field strengths and forces in **Question 3(c)(i)** and potentials and charges in **Question 3(c)(ii)**.
The definition of half-life and the completion of the decay equation in **Question 6** were not well known.
Better performing candidates were able to apply their knowledge to unfamiliar situations.
In calculations, stronger responses showed clear workings in a logical sequence.

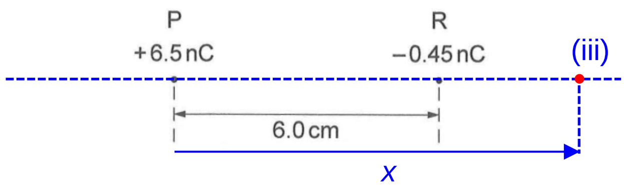
Qns		Marks
1(a)	$T = 2\pi\sqrt{\frac{m}{k}}$ $T^2 = (4\pi^2)\frac{m}{k}$ $k = (4\pi^2)\frac{m}{T^2}$ $= (4\pi^2)\frac{120\times10^{-3}}{(7.2\div10)^2}$ $= 9.14\text{ N m}^{-2}$ $\frac{\Delta k}{k} = \frac{\Delta m}{m} + 2\frac{\Delta T}{T}$ $\Delta k = k\left(\frac{\Delta m}{m} + 2\frac{\Delta T}{T}\right)$ $= (9.13852)\left(\frac{1}{100} + 2\frac{0.2}{7.2}\right)$ $= 0.599 = 0.60\text{ N m}^{-2}$ $k = (9.1 \pm 0.6)\text{ N m}^{-2}$	C1 (correct value of *k*) C1 (correct uncertainty relationship) C1 (intermediate value of Δ*k* correct to 2 sf) A1 (both qty given to 1 d.p.)

Qns		Marks
1(b)(i)	$v = \pm\omega\sqrt{x_0^2 - x^2}$ $\lvert v_0 \rvert = \lvert \omega x_0 \rvert$ $\omega = \frac{v_0}{x_0}$ $\lvert a_0 \rvert = \lvert \omega^2 \rvert x_0$ $= \left(\frac{v_0}{x_0}\right)^2 x_0 = \frac{v_0^2}{x_0}$ $= \frac{1.4^2}{0.16}$ $= 12.3 \text{ m s}^{-2}$ $\left(\text{accept } 12.25 \text{ m s}^{-2}\right)$	C1 C1 A1
1(b)(ii)	 B1: [values] start from max *x* and shows decreasing amplitude in next two *x*-intercepts B1: [shape] open (not closed) oval shape that is always smaller than printed	

Qns		Marks
2(a)(i)	A physical quantity that has both magnitude and direction	B1
2(a)(ii)	acceleration	B1
2(b)(i)	$W\ \sin\theta = (16)\sin 35° = 9.18$ N	A1
2(b)(ii)	  assume magnitude of friction remains constant direction of friction opposes relative motion $\lvert P\rvert = \lvert\text{friction}\rvert + \lvert W\ \sin(35°)\rvert$ $= 2\lvert(16)\ \sin(35°)\rvert$ $= 18.4$ N	C1 A1
2(c)(i)	impulse on X $= \Delta p_X$ $= p_{X,\text{ final}} - p_{X,\text{ initial}}$ $= m_X\left(v_{X,\text{ final}} - v_{X,\text{ initial}}\right)$ $= (0.22)(3.5 - 2.6)$ $= 0.198$ N s	C1 A1

Qns		Marks
2(c)(ii)	By Newton's 3rd Law, force exerted by X and Y is the same magnitude, same type, and opposite direction as force exerted by Y on X. Since the forces act over the same duration of time (during which the two bodies are in contact), the magnitude of change in momentum (impulse) is same on X on Y and Y on X. $\Delta p_Y = -\Delta p_X = -0.198 \text{ N s}$ $\Delta p_Y = p_{Y,\text{ final}} - p_{Y,\text{ initial}}$ $= m_Y \left(v_{Y,\text{ final}} - v_{Y,\text{ initial}}\right)$ $-0.198 = (0.40)\left(v_{Y,\text{ final}} - 3.3\right)$ $v_{Y,\text{ final}} = \dfrac{-0.198}{0.40} + 3.3$ $= 2.8 \text{ m s}^{-1}$ $\left(\text{accept } 2.81 \text{ m s}^{-1}\right)$	C1 A1
2(c)(iii)	area under velocity-time graph gives displacement, the magnitude of displacement since X continues in the same straight-line direction area under graph during contact $= \dfrac{1}{2}(2-1.8)(3.5+2.6)$ $= 0.61 \text{ m}$	M1 A1

Qns		Marks
3(a)	For both uniform gravitational and electric field, the constant force is parallel to the field lines, thus perpendicular to the initial velocity, which gives rise to a parabolic path.	B1 B1
3(b)(i)	The direction of the forces is opposite of each force; gravitational force is always attractive and so the force is directed opposite to the displacement from one proton to another electrostatic force is repulsive between two positively-charged protons so the force is directed in same direction as displacement from one proton to another	B1 B1
3(b)(ii)	the horizontal axis can be of same scale as both forces follow inverse-square law relationship and tends towards zero at large displacements the vertical axis is different, the magnitude of gravitational force is almost negligible compared to that of electric force at the same displacement and so the scale for gravitational force should be much smaller compared to that of electric force	B1 B1
3(c)	Note: it is important to read through entire question before attempting. Doing so would have allowed us to pick up that 3(c)(i) vs 3(c)(ii) directs the candidate to compare / contrast the difference between the vector and scalar quantities of field strength and potential	
3(c)(i)	electric field strength is never zero because a small positive test charge along the straight line will always experience an electric force directed towards R due to the vector sum of repulsive force from P and attractive force to R OR electric field strength due to P is same in direction to electric field strength due to Q, the vector sum of these electric field is therefore never zero.	B1
3(c)(ii)	electric potential is zero at a point nearer R because potential is a scalar sum of the positive potential due to P and negative potential due to R	B1

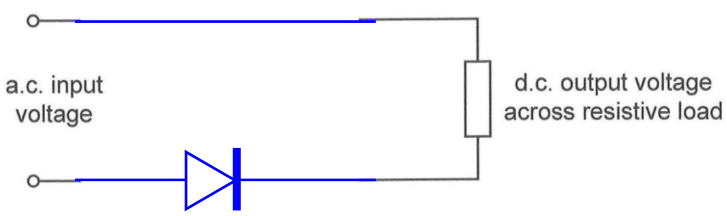
Qns		Marks
3(c)(iii)	Note: part (c)(i) is <u>between</u> but this part can be outside of PR  Let x be distance to the right of P where electric field strength is zero $\lvert E_P \rvert = \lvert E_R \rvert$ $\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{Q_P}{x^2} = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{Q_R}{\left(x - 6.0\times10^{-2}\right)^2}$ $\frac{6.5\times10^{-9}}{x^2} = \frac{0.45\times10^{-9}}{\left(x - 6.0\times10^{-2}\right)^2}$ $x = 0.0814$ m	C1 A1

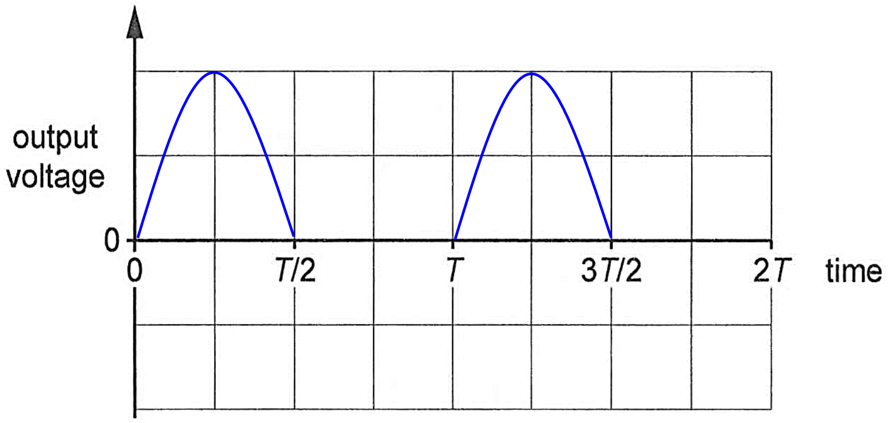
Qns		Marks
4(a)	gas particles are in continuous random motion and experience changes in momentum when they collide with inner walls of container by Newton's 2nd Law, a gas particle experiences a force from the rate of change in momentum during collision by Newton's 3rd Law, there is a force exerted on the wall that is equal in magnitude and opposite in direction to the force exerted on the gas particle the many collisions by all the particles averaged across time gives a constant force which when applied across the area of the inner walls, results in pressure	4 mark points -1 per missing mark point B3
4(b)(i)	average separation much larger than size of molecules	B1
4(b)(ii)	estimate using cubic geometry where molecules are situated at vertices of simple cube $pV = NkT$ $N = \frac{pV}{kT}$ $= \frac{(180)(3.2\times10^{-4})}{(1.38\times10^{-23})(298)}$ $= 1.40\times10^{19}$ Average distance $= \left(\frac{3.2\times10^{-4}}{1.40\times10^{19}}\right)^{1/3}$ $= 2.84\times10^{-8}$ m	C1 C1 (ave volume) A1
4(b)(iii)	the estimated average distance is 2 orders of magnitude larger than the approximate diameter of a gas particles so the average separation is indeed much larger than the size of the molecules	B1

Qns		Marks
5(a)	1. the wave profile of a stationary wave does not advance but the wave profile of a progressive wave advances in the direction of energy transfer of the wave 2. the wavelength of a stationary wave is twice the distance between 2 adjacent nodes or antinodes but the wavelength of a progressive wave is the distance between adjacent points on the wave having the same phase 3. the amplitude of oscillation for the particles on a stationary wave varies from zero at nodes to maximum at antinodes for a stationary wave but the amplitude is the same for all particles in the wave regardless of position 4. for a stationary wave, all particles within 2 adjacent nodes oscillate in phase and particles on either sides of a node oscillate in anti-phase but for a progressive wave, all particles within 1 wavelength have different phases ranging from 0 to 2π	any 2 B2
5(b)	Microwaves emitted from point source reflects off the metal plate back towards the point source such that the reflected wave is antiphase from the incident wave The incoming and reflected wave travel in opposite directions towards each other, meet and superpose along the line joining the point source normal to the metal plate, and a node is formed at the metal plate.	B1 B1
5(c)(i)	waves from emitter directly and after reflecting off the metal plate meet and overlap at detector with **different path lengths** emitter is a point-source so the intensity of waves decreases according to inverse square law of distance and so the **reflected wave has lower amplitude** **incomplete destructive interference** so intensity, which is proportional to square of amplitude, is never zero	B1 B1 B1
5(c)(ii)	distance between adjacent maxima is half wavelength Note: see 5(a) suggested mark point 2. Reminder: important to read through whole questions before attempting distance between 3 maximas $= 7.5 - 1.0$ $= 6.5$ cm $\lambda = \frac{6.5}{1.25}$ $= 5.2$ cm	A1
5(c)(iii)	$c = f\lambda$ $f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{3.4667 \times 10^{-2}}$ $= 8.65 \times 10^{9}$ Hz	C1 A1

Qns		Marks
6(a)	average time for activity or number of unstable nuclei to be reduced to one half of initial value, $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$	B1
6(b)	radioactive process is random which results in fluctuations in the graph more significant change in activity or number of unstable nuclei at steeper regions, so the percentage uncertainty due to fluctuations contributed by the random radioactive process is less significant	B1 B1
6(c)	Nucleus is initially stationary so by law of conservation of momentum, the vector sum of momenta of products should be zero Beta particle has momentum in the vertical direction as well as horizontal position but recoiling nucleus only has momentum in horizontal direction so there has to be another particle with some or all momentum in vertical direction	B1 B1
6(d)(i)	${}^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + {}^{0}_{-1}\text{e} + \bar{\nu}$	B1 B1 B1
6(d)(ii)	gradient of graph gives decay constant λ $A = \lambda N$ $\text{gradient} = \frac{y_1 - y_2}{x_1 - x_2}$ $= \frac{(5.2 - 1.0) \times 10^9}{(6.8 - 1.3) \times 10^{18}}$ $= 7.63 \times 10^{-10}$ $\lambda = 7.63 \times 10^{-10}\ \text{s}^{-1}$ $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ $= 9.1 \times 10^8\ \text{s}$	 C1 A1

Qns		Marks
6(e)	$J \rightarrow K$ $N_J = N_0 \exp(-\lambda t)$ $\dfrac{N_J}{N_0} = \exp\left(-\dfrac{\ln 2}{t_{\frac{1}{2}}} t\right) = \exp(-(\ln 2)(3.5))$ $= 0.088388$ $\dfrac{N_K}{N_0} = 1 - 0.088388$ $\dfrac{N_J}{N_K} = \dfrac{N_J}{N_0} \div \dfrac{N_K}{N_0}$ $= \dfrac{0.088388}{1 - 0.088388}$ $= 0.0970$ OR Consider $\dfrac{N}{N_o} = \left(\dfrac{1}{2}\right)^{\frac{t}{t_{1/2}}}$ $N_J = (N_J + N_K)\left(\dfrac{1}{2}\right)^{3.5}$ $2^{3.5} = \dfrac{N_J + N_K}{N_J} = 1 + \dfrac{N_K}{N_J}$ $\dfrac{N_J}{N_K} = \dfrac{1}{2^{3.5} - 1} = 0.0970$	 C1 C1 A1

Qns		Marks
7(a)(i)	$\dfrac{\text{cost to travel 1.0 km in the typical EV}}{\text{cost to travel 1.0 km in an ICE car}} = \dfrac{\frac{\$0.23 \times 72}{400}}{\$80 \div 800}$ $= 0.414$	A1
7(a)(ii)	The range of 400 km for one charge is larger than the average weekly travelling distance of 290 km	B1
7(b)(i)	there are minimally $32 \div 2 = 16$ parallel branches to supply 32 A of current $P = IV$ $V = \dfrac{P}{I} = \dfrac{7.2 \times 10^3}{32} = 225$ V potential difference across cells when charging is minimally 225 V so there is minimally $225 \div 3 =$ 75 cells in series per parallel branch there needs to be minimally $16 \times 75 = 1200$ cells	M1 M1 A1
7(b)(ii)	the range of the EV increases by 40 km per hour of charging [Note: Since range of EV is 400 km and it takes 10h to full charge, 400/40 = 40 km h^{-1}]	B1
7(b)(iii)	potential energy stored in the battery is $141 \times 60^2 = 507600$ J per unit mass of the battery	B1
7(b)(iv)	$m_{battery} = \dfrac{72 \times 10^3}{141}$ $= 511$ kg	A1
7(b)(v)	lowers the centre of gravity of the car, more stable, more likely to generate a restoring torque to cause car to upright itself if it ever rolls on its sides	B1
7(c)(i)		A1

Qns		Marks
7(c)(ii)		B1 (repeated half wave per cycle) B1 (zero for other half)
7(d)	$\text{KE stored} = \frac{1}{2}mv^2$ $= \frac{1}{2}(1685)(25)^2$ $= 526\ 562.5\ \text{J}$ $\text{average energy used per km} = \frac{72 \times 10^3 \times 60^2}{400}$ $= 648\ 000\ \text{J}$ $\text{distance} = \frac{526\ 562.5}{648\ 000}$ $= 0.813\ \text{km}$	C1 C1 A1
7(e)(i)	wireless charging is an application of electromagnetic induction a.c. voltage sets up the changing magnetic flux linkage needed to induce an e.mf. in the secondary coil located in the EV	B1
7(e)(ii)	To reduce loss of magnetic flux linkage / increase flux linkage between the charger and the coil in the EV	B1
7(f)(i)	$\text{max torque} = Fd_{\perp}$ $= (NBIL)d_{\perp} = NBI(A)$ $395 = (1200)(B)(96)(6.1 \times 10^{-3})$ $B = 0.562\ \text{T}$	C1 C1 A1
7(f)(ii)	creates radial / spoke-like magnetic field which maximises turning effect for 4 times per rotation, so smoother motor motion	B1

Paper 3
Longer Structured Questions

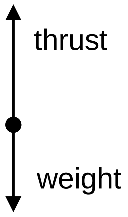
General Notes:

Candidates generally displayed strong mathematical skills. Sometimes candidates did not give their final numerical answer to an appropriate number of significant figures. The precision of the data supplied in a question is a guide to how many significant figures are appropriate.

There were several questions which required the candidates to apply their knowledge and understanding to specific contexts. Weaker responses simply stated a physics principle but did not explain how it applies to the specific context outlined in the question. In **Question 3b**, the concept of a contact force is relevant, but it is the absence of a contact force that leads to the water leaving the drum. In **Question 5b**, the change of magnetic flux inducing an electromotive force (e.m.f.) is important, but weaker responses did not make clear in which coil the relevant change is taking place.

There was a fairly even split of candidates answering the optional questions, with **Question 9** chosen slightly more than **Question 8**.

Qns		Marks
1(a)	the property of a body to resist its state of rest or motion in a straight line	B1
1(b)	$g=-\frac{GM}{r^2}$ $=-\frac{(6.67\times10^{-11})(7.35\times10^{22})}{(1.74\times10^{6})^2}$ $=-1.62\text{ N kg}^{-1}$	C1 A1
1(c)(i)	$F_{net}=\frac{m}{\Delta t}\Delta v$ $10.0\times10^{3}=(70.0)\Delta v$ $\Delta v=143\text{ m s}^{-1}$ [Note: Do not write *F=mΔv/Δt,* this is incorrect even if the subsequent substitution might be.	C1 C1 A1

Qns		Marks
1(c)(ii)	 $\Delta \text{mass}_{t=15\text{ s}} = (15.0)(70.0)$ $= 1050 \text{ kg}$ $\text{mass}_{t=15\text{ s}} = 4000 - 1050$ $= 2950 \text{ kg}$ $F_{net} = F_{thrust} - W$ $ma = F_{thrust} - mg$ $a = \frac{F_{thrust}}{m} - g$ $= \frac{10.0 \times 10^3}{2950} - 1.62$ $= 1.77 \text{ m s}^{-2}$	 C1 C1 A1
1(c)(iii)	at t=15 s, rocket is further from planet so g has decreased to less than 1.62 N kg^{-1} hence lower gravitational force experienced Larger net force experienced and by N2L, actual acceleration is larger.	M1 M1 A0

<table>
<tr><th>Qns</th><th></th><th>Marks</th></tr>
<tr><td>2(a)</td><td>$R = \frac{\rho L}{A} = \frac{\rho L}{\pi\left(\frac{d}{2}\right)^2} = \frac{4\rho L}{\pi d^2}$

$\frac{R}{L} = \frac{\rho}{\pi r^2}$

$\rho = \frac{\pi d^2}{4}\left(\frac{R}{L}\right)$
$= \frac{\pi\left(1.02\times10^{-3}\right)^2}{4}(1.73)$
$= 1.41\times10^{-6}\ \Omega\ \text{m}$</td><td>C1

C1

A1</td></tr>
<tr><td>2(b)(i)</td><td>

time after being switched on / s	ΔU	q	w
0 – 59	positive	negative	positive
60 - 100	zero	negative	positive

Notes:
ΔU after 60 s: wire remains constant temperature so internal energy remains constant, no change

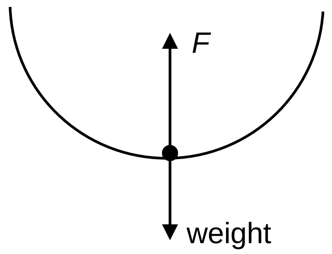
Work is done on the metal wire by the power supply thus w is positive

but constant temperature that is higher than ambient, so heat is lost to surrounding, so q is negative, and $w = q$ in magnitude</td><td>each mismatch -1

B2</td></tr>
<tr><td>2(b)(ii)</td><td>$\Delta U = 0$
(because constant temperature)

$P = \frac{w}{t} = IV$
$w = IVt$
$= (12)(230)(40)$
$= 110\ 000\ \text{J}$ (accept 110 400 J)

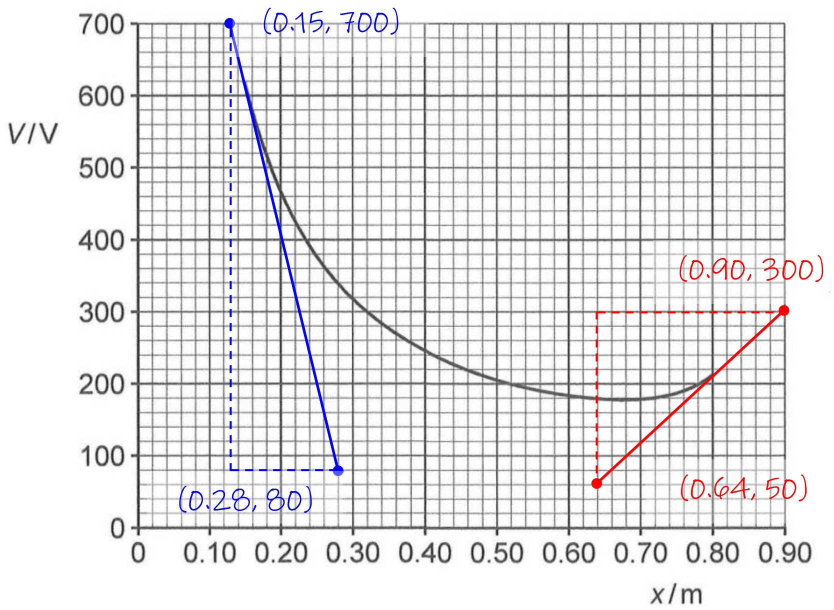
$q = -w = -110\ 000\ \text{J}$</td><td>A1 each</td></tr>
</table>

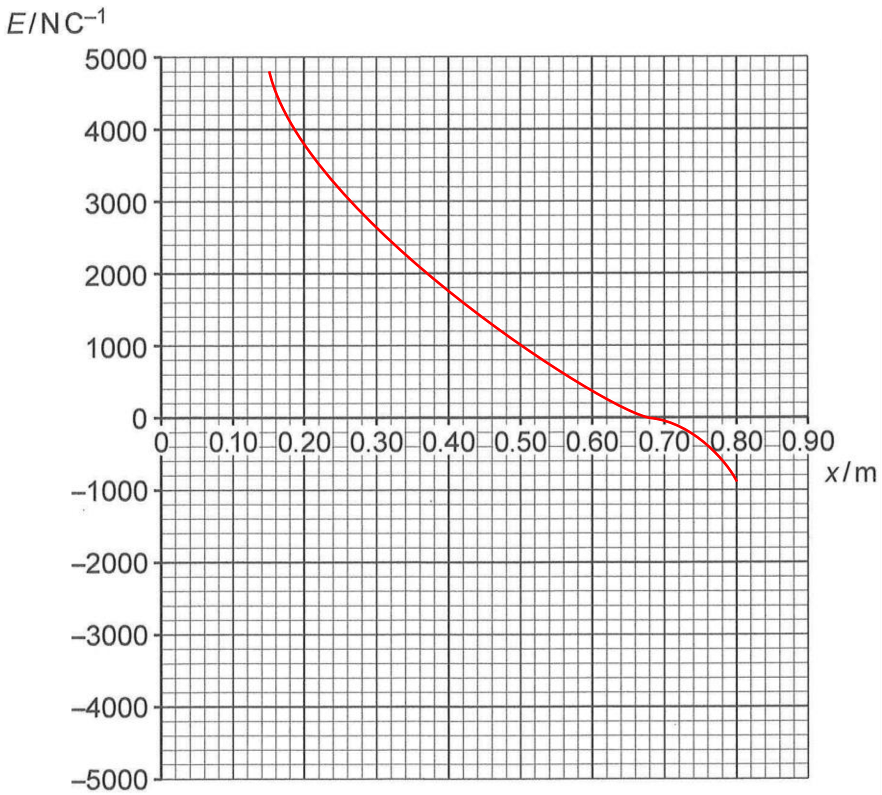
Qns		Marks
3(a)(i)	$\omega = 2\pi f$ $= 2\pi\left(\frac{1200}{60}\right)$ $= 126 \text{ rad s}^{-1}$	C1 A1
3(a)(ii)	 $F_c = F - W$ $F = F_c + mg$ $= mr\omega^2 + mg = m\left(r\omega^2 + g\right)$ $= (1.20)\left((0.230)(126^2 + 9.81\right)$ $= 4380 \text{ N}$ towel experience 4380 N of force upwards	C1 A1 B1
3(a)(iii)	[direction] clothes experience force that points towards centre of drum by newton's third law, the drum experiences forces that vary in direction all around 360 degrees with each drum spin [magnitude] clothes can experience forces of about 300 times larger than their weight; for a typical full load of clothes of about 8 kg the drum can experience up to 24 000 N of force Large masses near the bottom lowers the centre of gravity of the washing machine, prevents toppling due to the changing force directions and keeps contact of washing machine with surface Solution from green tys: Washing machines vibrate vigorously when spinning. The large masses serve as a mass damper by reducing the amplitude A of vibration, since $A = \sqrt{\frac{2E}{m\omega^2}}$ where E is the total energy. The masses also reduce the natural frequency f to a very low value since $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ so that it is far below the frequency of spinning. The large masses are also placed at the bottom to lower the centre of gravity of the washing machine, increasing its stability to reduce the chance of it toppling when it vibrates, and also to prevent the large force in (a)(ii) from cracking the base.	B1 B1 B1

Qns		Marks
3(b)	holes in the walls of drum cannot provide normal contact force that contributes to the centripetal force on clothes and water spinning in drum water tends to continue in state of constant velocity and exits tangential to the drum	B1 B1

Qns		**Marks**
4(a)	Scalar method Net potential is scalar sum of potentials contributed by A and B Since graph is positive at every point between A and B and there exist a minimum potential spheres are of same sign and charge sign of A is positive Vector method Field strength is numerically equal to negative potential gradient At x = 0.68 m, gradient = 0, so $E_{net} = 0$ Since E_{net} is vector sum of electric field strengths contributed by A and B, $E_A = -E_B$, electric field directions by A and B and opposite which means that their charge signs are the same. Since gradient near A is negative, E_A is positive, so charge sign of A is positive.	B1 B1 B1

Qns		Marks
4(b)	magnitude of electric field strength is numerically equals to the electric potential gradient and acts in the direction of decreasing potential	

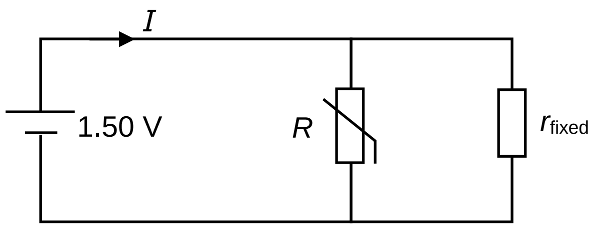




			Marks
$E = -\dfrac{dV}{dx}$ $\approx -\dfrac{700-80}{0.15-0.28}$ $= 4770\ \text{N C}^{-1}$	$E = -\dfrac{dV}{dx}$ $\approx -\dfrac{300-60}{0.90-0.64}$ $= -923\ \text{N C}^{-1}$	$E = 0$ when $x = 0.68$ m	M1 (calculated E value) A1 (plotted to half-square accuracy) M1 (calculated E value) A1 (plotted to half-square accuracy) B1

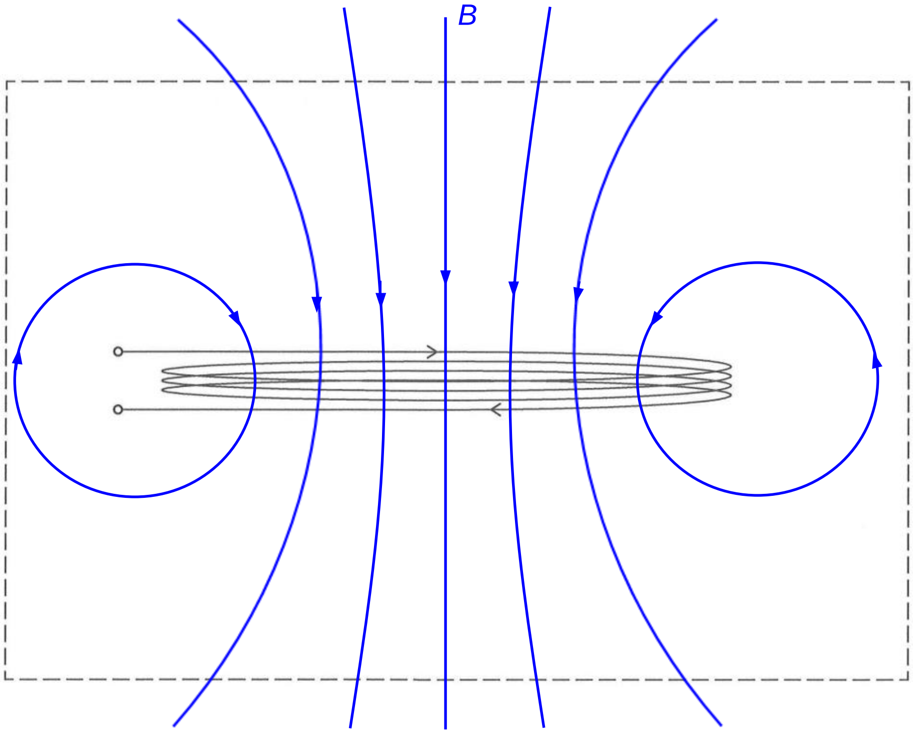
Qns		Marks
4(c)(i)	$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ $= \frac{1}{4\pi\varepsilon_0}\frac{1.0\times10^{-8}}{0.15}$ $= 600$ V	C1 A1
4(c)(ii)	Resultant potential at surface is due to scalar addition of potential due to charge on A and potential due to charge on B Both charges are positive so the resultant potential is larger than 600 V which is just due to charge on A	B1 B1

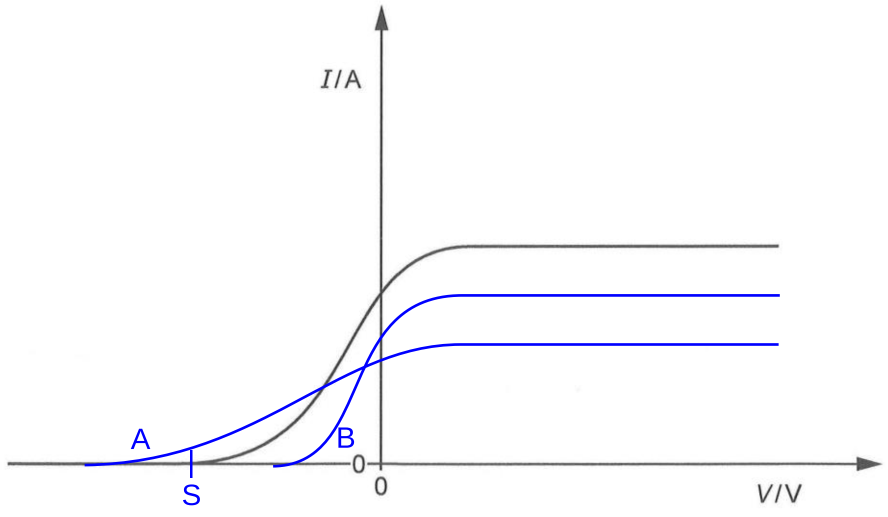
Qns		Marks
5(a)	immediately after switch is closed, voltmeter reading **rises to a maximum value in a short amount of time** and returns quickly to zero	B1
	maintains at **zero** for a short duration of time	B1
	immediately after switch is re-opened, voltmeter reading rises to another maximum value that is **opposite polarity to the initial** change on switch closing before returning to zero	B1
5(b)	when switch is closed, input current in primary coil increases from zero to a maximum value in a short amount of time	B1
	the magnetic field in primary coil is changed from zero to a maximum value	B1
	resulting in increasing magnetic flux linkage with secondary coil	B1
	by Faraday's Law, electromotive force is induced in secondary coil and is directly proportional to rate of change of magnetic flux linkage	B1
	when switch is opened, the decrease in input current eventually results in decreasing magnetic flux linkage with secondary coil and hence an induced e.m.f. opposite to the to that during switch closing	B1
	when the switch remained closed or opened, the magnetic flux linkage with the secondary coil is constant so there is zero rate of change of magnetic flux linkage, hence zero induced e.m.f..	

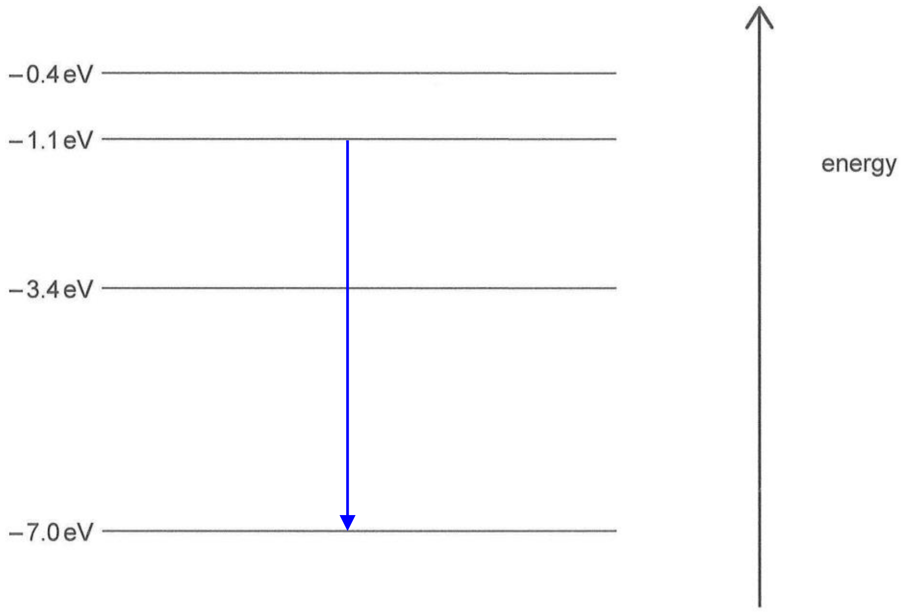
Qns		Marks
6(a)	$T = 20\ °C,\ R = 60\ \Omega$ $V_R = IR$ $I = \frac{V_R}{R}$ $= \frac{1.5 - 0.43}{60} = 0.0178\ A$ $e.m.f. = V_R + V_{fixed}$ $V_{fixed} = Ir_{fixed}$ $r_{fixed} = \frac{V_{fixed}}{I}$ $= \frac{0.43}{0.017833}$ $= 24.112 \approx 24\ \Omega$	 C1 C1 M1 A0
6(b)	 $T = 32\ °C,\ R = 40\ \Omega$ $\frac{1}{R_{eff}} = \frac{1}{R} + \frac{1}{r_{fixed}} = \frac{1}{40} + \frac{1}{24}$ $R_{eff} = 15\ \Omega$ $I = \frac{e.m.f}{R_{eff}}$ $= \frac{1.50}{15}$ $= 0.10\ A$	 C1 C1 A1

Qns		Marks
7(a)	waves have constant phase difference	B1
7(b)	$d\ \sin\theta = n\lambda$ $\frac{L}{N}\sin\theta = n\lambda$ $\left(d = \frac{L}{N} = \frac{10^{-3}}{300} = 3.33\times10^{-6}\right)$ $\theta = \sin^{-1}\left(\frac{Nn\lambda}{L}\right)$ $\left(\theta = \sin^{-1}\left(\frac{300(2)(640\times10^{-9})}{10^{-3}}\right) = 22.58°\right)$ $\tan\theta = \frac{\text{distance from central to 2nd order max}}{\text{screen distance}}$ $\text{distance} = (\text{screen distance})(\tan\theta)$ $= (\text{screen distance})\left(\tan\left[\sin^{-1}\left(\frac{Nn\lambda}{L}\right)\right]\right)$ $= 0.873\text{ m}$ $= 87.3\text{ cm}$	either C1 or C1 C1 C1 A1

Qns		Marks
8(a)(i)	electric force per unit positive charge on a small stationary test charge at that point	B1
8(a)(ii)	Prevent emitted electrons from colliding with air molecules and hence affecting number and speed of electrons reaching anode	B1 B1
8(a)(iii)	By conservation of energy, increase in kinetic energy of electrons = loss of electric potential energy of electrons $2.48\times10^{-16}=e\Delta V$ $\Delta V=\dfrac{2.48\times10^{-16}}{1.60\times10^{-19}}$ $=1550\text{ V}$	M1 A1
8(a)(iv)	emission occurs when electrons in cathode gains sufficient thermal energy to overcome work function of cathode (note: as opposed to photoelectric effect where instead of thermal energy, electrons receive photon energy) electrons near cathode surface are emitted with maximum kinetic energy for electrons that are not at the surface, some energy is required to bring the electron up to the surface before emission OR From Fig 8.2, electrons are emitted in all directions, hence for given speed there would be a range of velocities parallel and normal to cathode Velocity normal to cathode increases due to acceleration by electric field Velocity parallel to cathode remains constant So range of final velocity arriving at anode	C0 B1 B1
8(b)(i)	Magnetic flux density due to flat circular coil: $B=\dfrac{\mu_0 NI}{2r}$ $=\dfrac{(4\pi\times10^{-7})(120)(3.5)}{2\left(\frac{30}{2}\times10^{-2}\right)}$ $=0.00176\text{ T}$	 C1 A1

Qns		Marks
8(b)(ii)		B1 symmetric left-right B1 field lines parallel, points in same direction, and vertical for the segment in the plane of the flat circular coil B1 Presence of complete loops "outside" the coil
8(c)(i)	Magnetic force is always perpendicular the direction of the velocity so magnetic force provides centripetal force on particle no displacement in the direction of the force, no work done on electron and therefore no change in kinetic so constant speed [Note: since v remains constant and F=Bqv, magnetic force remains constant]	B1 B1 B1
8(c)(ii)	magnetic force provides centripetal force on particle $Bqv = \frac{mv^2}{r}$ $r = \frac{mv}{Bq}$ $= \frac{(9.11\times10^{-31})(2.40\times10^{7})}{1.43(0.0017593)(1.60\times10^{-19})}$ $= 0.0543$ m	 C1 C1 A1
8(d)	Particle has velocity along two components in terms of direction the component of velocity normal to the magnetic field results in uniform circular motion the component of velocity parallel to the magnetic field causes displacement along the magnetic flux line as the particle performs circular motion, resulting in a helical path	 B1 B1

Qns		Marks
9(a)	a single photon can interacts with and pass on all of its energy to a single electron in an one-to-one process, a photon is a discrete packet of energy of electromagnetic radiation and the energy of one photon is directly proportional to the frequency of electromagnetic radiation *E* = *hf* the maximum kinetic energy of emitted individual photoelectron is due to one photon of sufficiently high frequency interacting with electrons at the metal surface an electron cannot accumulate sufficient wave energy from low intensity light across a time duration for emission. ** Need help improving this to better answer question	B1 B1 B1 B1
9(b)	Threshold frequency	
9(c)	$hf = \Phi + KE_{max}$ $KE_{max} = \frac{hc}{\lambda} - \Phi$ $= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{210\times10^{-9}} - (4.33)(1.60\times10^{-19})$ $= 2.54\times10^{-19}$ J	C1 C1 convert eV to J A1
9(d)	By conservation of energy, loss of KE = gain in electric potential energy $KE = eV_s$ $V_s = \frac{KE}{e}$ $= \frac{2.5434\times10^{-19}}{1.6\times10^{-19}}$ $= 1.59$ V	C1 A1
9(e)		

Qns		Marks
9(e)(iv)	The stopping potential is the minimum potential difference between the emitting metal and collector that prevents the most energetic photoelectrons from reaching the collector plate for potential differences **equal or larger than the stopping potential**, the kinetic energy of the most energetic photoelectrons is insufficient to do work against the electric field to reach the collect plates	B1 idea minimum p.d. so the range of p.d.s is clear B1 idea of energy conversion
9(f)(i)	 $E_{\text{in eV}} = \dfrac{hc}{\lambda e}$ $= \dfrac{(6.63\times10^{-34})(3.00\times10^{8})}{(210\times10^{-9})(1.60\times10^{-19})}$ $= 5.92$ eV	
9(f)(ii)	Longest wavelength means shortest frequency and thus involves the de-excitation of an electron from a higher discrete energy level to a lower discrete energy level across the smallest possible difference in energy levels Electron de-excites from – 0.4 eV to – 1.1 eV $E_{\text{in eV}} = \dfrac{hc}{\lambda e}$ $\lambda = \dfrac{hc}{E_{\text{in eV}}e}$ $= \dfrac{(6.63\times10^{-34})(3.00\times10^{8})}{(-0.4-(-1.1))(1.60\times10^{-19})}$ $= 1.78\times10^{-6}$ m	C1 A1