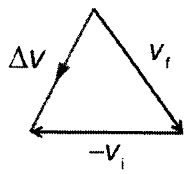
Qn	Ans	Discussion
1	C	The object travels at the same speed. Hence, $\lvert v_f \rvert = \lvert v_i \rvert$. $\Delta v = v_f - v_i$ $= v_f + (-v_i)$ 
2	A	For the upward motion, air resistance and gravitational force are both acting downwards, acceleration is greater than the acceleration of free fall and hence it decelerates faster to reach the maximum height. As for the downward motion, air resistance and gravitational force are in opposite directions and the resultant force equals to gravitational force minus the air resistance. Acceleration is smaller than the acceleration of free fall and hence it accelerates slower downwards than it decelerates upwards.
3	D	Consider cart 3 and cart 4 as single object of mass 800 kg. Only *T* is acting on this object. $F = ma$ $T = 800\ (2) = 1600$ N
4	A	Assuming the mass of each ball is *m*. Since total initial momentum = mv By Conservation of linear momentum, total final momentum should be mv A) Total final momentum = $0 + mv = mv$ B) Total final momentum = $\frac{mv}{2} + \frac{mv}{2} = mv$ C) Total final momentum = $\frac{3mv}{4} - \frac{mv}{4} = \frac{1}{2}mv$ D) Total final momentum = $mv - mv = 0$ Only A and B's momentum are conserved. Elastic means relative velocity of approach = relative velocity of separation By relative velocity of approach and separation, KE not conserved for option B.
5	A	By conservation of energy, elastic potential energy is converted to kinetic energy and work done against friction. As height is the same at initial and final positions, gravitational potential energy is unchanged. $EPE_{loss} = KE_{gain} + WD_{friction}$ $\frac{1}{2}kx^2 = (KE_{final} - KE_{initial}) + fd$ $KE_{final} = \frac{1}{2}kx^2 - fd$ (since $KE_{initial} = 0$)

6	**D**	$N - mg = \frac{mv^2}{r}$ $N = mg + \frac{mv^2}{r}$ $= 0.52\left(\frac{9.3^2}{1.3} + 9.81\right)$ $= 39.7$ ≈ 40 N
7	**A**	Resultant $g = 2 \times \frac{(6.67 \times 10^{-11})(30)}{(\sqrt{10^2 + 10^2})^2} \cos 45°$ $= 1.4 \times 10^{-11}$ N kg^{-1} upwards Resultant $\phi = 2 \times -\frac{(6.67 \times 10^{-11})(30)}{(\sqrt{10^2 + 10^2})}$ $= -2.8 \times 10^{-10}$ J kg^{-1}
8	**C**	E_k at $r = \frac{GMm}{2R} = 3.2$ MJ E_p at $r = -\frac{GMm}{R} = -6.4$ MJ E_p at $2r = -\frac{GMm}{2R} = -3.2$ MJ
9	**B**	Since they have the same volume and pressure initially, they must have the same *T*. Therefore when the partition is removed, the *P* and *T* remains the same.
10	**B**	Since temperature is the same, the average kinetic energy is the same. $\langle E_k \rangle = \frac{1}{2} m \langle c^2 \rangle$ $\langle c^2 \rangle \propto \frac{1}{m}$ $\frac{c_{rms,X}}{c_{rms,Y}} = \sqrt{\frac{m_Y}{m_X}}$ $= \sqrt{\frac{1}{2}}$ $= 0.71$
11	**B**	$\Delta U = Q + W$ For path 1, $\Delta U = 10 + (-4) = +6$ J For path 2, ΔU is the same. $6 = Q + (-2)$ $Q = +8$ J

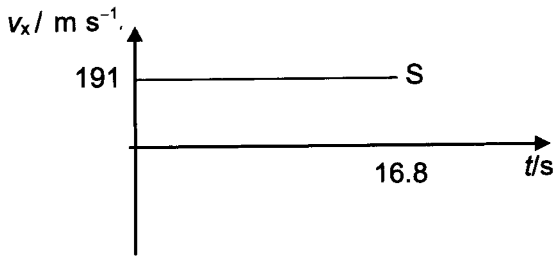
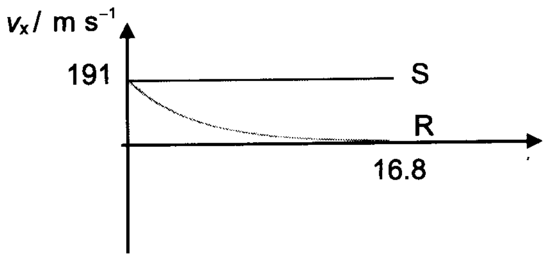
12	**A**	Characteristic of heavy damping.
13	**C**	$a_0 = \omega^2 x_0$ $6.0 = \omega^2(0.30)$ $\omega = 4.47$ $\approx 4.5 \text{ rad s}^{-1}$
14	**B**	P and S are at the centre of regions of compression. T is at the centre of a region of rarefaction. The centre of regions of compression has a phase difference of π from the centre of regions of rarefaction.
15	**D**	$T = 4(4.0\times10^{-5}) = 1.6\times10^{-4}$ s $f = \frac{1}{T} = \frac{1}{1.6\times10^{-4}} = 6250$ Hz $\lambda = \frac{v}{f}$ $= \frac{330}{6250}$ $= 5.3$ cm
16	**B**	$\lambda = \frac{ax}{D}$ $x = \frac{\lambda D}{a}$ x is directly proportional to λ. However, the graph does not start from the origin.
17	**B**	$\theta \approx \frac{\lambda}{b}$ applying small angle approximation, $\frac{x}{D} = \frac{\lambda}{b}$ $x = \frac{\lambda D}{b}$ $= \frac{(0.40\times10^{-6})(2.8\times10^{25})}{5.1}$ $= 2.2\times10^{18}$ m
18	**D**	no. of wavelengths $= \frac{33.5}{12} = 2.79$ Since X is an intensity maxima (antinode), an intensity minima (node) will be detected at 0.25λ, 0.75λ, 1.25λ, 1.75λ, 2.25λ and 2.75λ away from X.

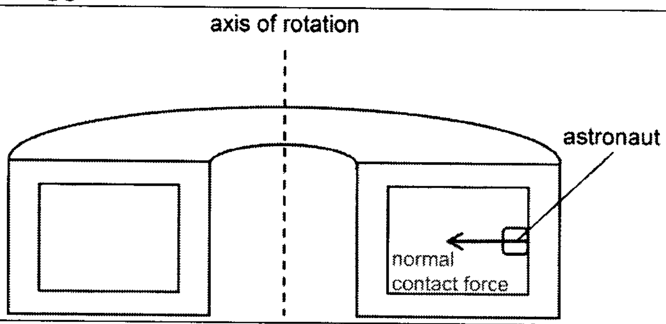
19	C	Between parallel charged plates, the electric field E is uniform. Hence, the force $F = qE$ experienced by the α-particle is uniform at any position in between the two plates.
20	D	Option A is incorrect as potential is a work done per unit charge / work done per unit mass. Option B is incorrect as potential is inversely proportional to r and not r^2. Option C is incorrect as electric potential can be positive if the object is positively charged. Option D is correct since moving along a field line implies moving from one equipotential line to another so the potential changes.
21	A	$I = nevA$ $v = I/neA$ since I, n, e are constants $v \propto 1/A \propto 1/d^2$ $\frac{v_y}{v_x} = \frac{d_x^2}{d_y^2}$ $\frac{v_y}{v_x} = \frac{(d)^2}{(2d)^2} = 0.25$
22	A	As V increases, I/V ratio increases, V/I ratio decreases, R decreases.
23	B	Effective resistance of right portion increases. Using potential divider principle, S is brighter than before, while P and R are dimmer than before.
24	A	Using the right-hand grip rule at each wire position, the resultant magnetic field due to the contributions from the four wires are as follows: - Downwards at P - Rightwards at Q - Upwards at R - Leftwards at S
25	D	Electron experiences a magnetic force out of the page. $F_B = Bev\sin\theta$ For it to remain undeflected, the electric force must have the same magnitude. Hence, $E = \frac{F_E}{e} = Bv\sin\theta$ The electric force must point into the page. Since an electron is negatively charged, the electric field points out of the page.

26	**B**	$\Delta\phi$ for one rotation $= BA$ magnitude of $\varepsilon = \dfrac{d\phi}{dt}$ $= \dfrac{BA}{T}$ $= \dfrac{B(\pi r^2)}{\left(\dfrac{2\pi}{\omega}\right)}$ $= \dfrac{1}{2}Br^2\omega$ $= \dfrac{1}{2}(0.23)(0.65)^2(120)$ $= 5.8$ V Alternatively, magnitude of $\varepsilon = \dfrac{d\phi}{dt}$ $= B\dfrac{d}{dt}\left(\dfrac{1}{2}r^2\theta\right)$ $= B\left(\dfrac{1}{2}r^2\right)\left(\dfrac{d\theta}{dt}\right)$ $= \dfrac{1}{2}Br^2\omega$ $= \dfrac{1}{2}(0.23)(0.65)^2(120)$ $= 5.8$ V
27	**B**	For a rectified square wave, $V_{rms} = \sqrt{\dfrac{V_0^2\left(\dfrac{T}{2}\right)}{T}}$ $= \dfrac{V_0}{\sqrt{2}}$ $P_{ave} = \dfrac{V_{rms}^2}{R}$ $= \left(\dfrac{V_0}{\sqrt{2}}\right)^2 \dfrac{1}{R}$ $= \dfrac{V_0^2}{2R}$
28	**D**	energy of photon $= \dfrac{hc}{\lambda}$ $= \dfrac{(6.63\times10^{-34})(3.0\times10^{8})}{(650\times10^{-9})}$ $= 1.9$ eV Transition from E_3 to E_2 gives the same energy.
29	**B**	The p.d. through which the electrons are accelerated will increase the kinetic energy of the electrons. This will increase the maximum energy of X-rays emitted, reducing the cut-off wavelength of the spectrum. The characteristic wavelengths remain unchanged as the target is not changed.

30	**A**	The correct answer describes a piece of evidence that uniquely identifies α-radiation. - Option A is correct because the count rate only reduces significantly 1 cm away from the source in air if it is α-radiation. β and γ radiation have greater penetrating power. - Option B is incorrect because a lead block can shield α, β and γ radiation. - Option C is incorrect because both α and β particles are charged and can be deflected by a perpendicular electric field. - Option D is incorrect because a parallel magnetic field will not deflect α, β and γ radiation.

Qn	Suggested Solutions
1(a)(i)	$\Delta p = mv - mu$ $= 0.140\left(-4.0 - (5.4)\right)$
	$\Delta p = -1.3$ N s
(ii)	$F = \left\|\frac{\Delta p}{\Delta t}\right\| = \frac{1.3}{0.04} = 32.5$ N
	$F = N - mg$ $32.5 = N - 0.14(9.81)$ $N = 34$ N
	By Newton's 3rd law, magnitude of the force exerted by the ball on the bar = magnitude of the force by the bar on the ball, *N*
(b)	Taking moments about B,
	$34(75) + 0.450(9.81)(25) = F_A(20)$
	$F_A = 133$ N

Qn	Suggested Solutions
2(a)(i)	$s_y = u_y t + \frac{1}{2} a_y t^2$ $x = 220\sin(30^\circ)(16.8) + \frac{1}{2}(9.81)(16.8)^2$
	$x = 3230$ m
(ii)	$v_x = u_x = 220\cos(30^\circ) = 190.5$ m s^{-1}
	$v_y = u_y + a_y t$ $v_y = 220\sin(30^\circ) + 9.81(16.8) = 274.8$ m s^{-1}
	$v = \sqrt{v_x^2 + v_y^2}$ $v = \sqrt{190.5^2 + 274.8^2}$ $v = 334$ m s^{-1}
	OR
	initial $E_k = \frac{1}{2} m (220)^2$
	loss in gravitational $E_P = mgh$ $= m(9.81)(3232)$
	final kinetic energy = loss in gravitational potential energy + initial kinetic energy $\frac{1}{2} m v^2 = m(9.81)(3232) + \frac{1}{2} m (220)^2$ $v = 334$ m s^{-1}
(iii)	
(b)	

Qn	Suggested Solutions
3(a)	
(b)(i)	Although the magnitude of the velocity is constant, its velocity is changing as the direction of its velocity is always changing.
	According to Newton's Second Law, the astronaut must experience rate of change of momentum / an acceleration and hence a resultant force.
	Both the acceleration and force act towards the centre.
(ii)	$g = 9.81 = \frac{v^2}{r}$ $r = \frac{100^2}{9.81} = 1019$
	$r = 1020m$

Qn	Suggested Solutions
4(a)	A polarised wave has its vibrations/oscillations occur in a single direction in a plane / restricted to one plane (axis) and perpendicular to the direction of transfer of energy/propagation.
(b)	Applying Malus' Law and assuming that the intensity of the polarised light after polaroid Q is I_0, $I = I_0 \cos^2 \theta$ $= I_0 \cos^2 (30°)$ $= 0.75 I_0$
	Since $I \propto A^2$ $\frac{I}{I_0} = \left(\frac{A}{A_0}\right)^2$ $\cos(30°) = \frac{A}{A_0}$ $A = 0.866 A_0$ $\approx 0.87 A_0$
(c)	It is the spreading of the wave into its geometrical shadow when it is incident on an aperture/opening or edge of an obstacle.
(d)(i)	$d \sin\theta = n\lambda$ $(3.4 \times 10^{-6}) \sin\left(\frac{16°}{2}\right) = \lambda$
	$\lambda = 4.73 \times 10^{-7}$ m $\approx 4.7 \times 10^{-7}$ m
(ii)	Blue/Indigo
(iii)	For an emerging beam to be observed on the screen, $\theta \leq 90°$ and hence $\sin\theta \leq 1$.
	Since $\sin\theta = \frac{n\lambda}{d}$, $\frac{n\lambda}{d} \leq 1$ $n \leq \frac{d}{\lambda}$ $n \leq \frac{3.4 \times 10^{-6}}{4.73 \times 10^{-7}}$ $n \leq 7.19$
	no. of emerging beams $= 7 + 7 + 1 = 15$
(iv)	Without the polaroids, the incident light intensity on the diffraction increases, so the diffraction maxima become brighter.
	The separation between maxima depends only on the wavelength of light and the line spacing of the grating, which are unchanged, so it remains the same.

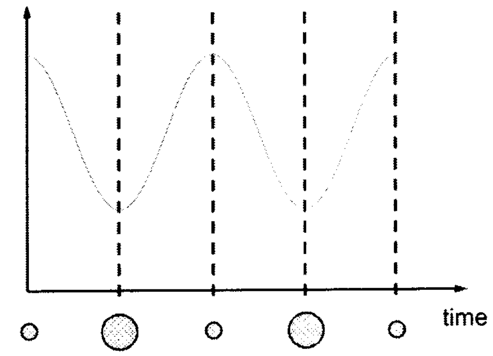
Qn	Suggested Solutions
5(a)	The resistance R of a circuit component is defined as the ratio of potential difference V across the conductor to current I flowing through the conductor.
(b)	current in series circuit $I = \frac{E}{R_{total}} = \frac{E}{A+B}$ pd across $A = IA = \left(\frac{E}{A+B}\right)A = \frac{A}{A+B}E$ (Shown)
(c)(i)	As the temperature of the thermistor is raised, its resistance will decrease.
	This will result in the combined resistance of the thermistor and the 4000 Ω resistance to decrease due to their parallel circuit arrangement.
	As a result, based on the potential divider principle, the potential difference across the 1500 Ω resistor will increase and hence, the voltmeter reading will increase.
(ii)	$\frac{1}{R} = \frac{1}{B} + \frac{1}{R_T}$ $\frac{1}{R} = \frac{1}{4000} + \frac{1}{2700}$ $R = 1612\ \Omega$
	$V = \frac{A}{A+R}E$ $V = \frac{1500}{1500+1612}(5)$
	$V = 2.41\text{ V}$
(iii)	With internal resistance, the effective resistance of the circuit increases / terminal p.d. decreases.
	For the same change in temperature (same change in thermistor's resistance), there is a smaller change in the voltmeter reading.

Qn	Suggested Solutions
6(a)	The magnetic flux density of a magnetic field is the force per unit length acting on a straight, current-carrying conductor,
	carrying unit current and placed at right angles to this external magnetic field.
(b)(i)	The wire exerts a downward force on the magnet.
	By Newton's third law, the magnet exerts an upward force on the wire.
(ii)	A to B
(iii)	$F = BIl\sin\theta$ $= BIl\sin(90°)$ $= (3.7\times10^{-3})(4.6)(8.5\times10^{-2})$
	$F = 1.447\times10^{-3}$ $\approx 1.4\times10^{-3}$ N
(iv)	Assume θ is the angle of rotation from the initial position. length of wire in magnetic field $= \dfrac{l}{\cos\theta}$
	$F = BI\left(\dfrac{l}{\cos\theta}\right)\left[\sin(90° - \theta)\right]$ $F = BI\left(\dfrac{l}{\cos\theta}\right)(\cos\theta)$ $F = BIl$ The force acting on the wire is independent of the angle of rotation.

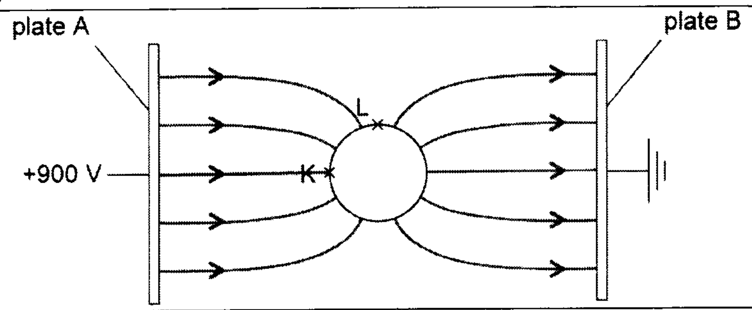
Qn	Suggested Solutions
7(a)	Binding energy per nucleon is a maximum/close to the maximum at around A = 56.
	Products of splitting a $^{56}_{26}\text{Fe}$ nucleus have a lower total binding energy which requires a net input of energy
(b)	energy released = BE of products − BE of reactants $=(1.273+0.8405-1.910)(1.66\times10^{-27})(3.00\times10^{8})^{2}$
	$=3.04\times10^{-11}$ J
(c)	$\lambda=\dfrac{\ln 2}{28.8\text{ yrs}}$ $N=N_0e^{-\lambda t}$ $\dfrac{N}{N_0}=e^{-\frac{\ln 2}{28.8}(144)}$ $=\dfrac{1}{32}$ $R=\dfrac{N_0-N}{N}$ $=\dfrac{N_0}{N}-1$ $=32-1$ $=31$ OR no. of half-lives $=\dfrac{144}{28.8}=5.00$ $N=\dfrac{N_0}{2^5}$ $=\dfrac{1}{32}N_0$ $R=\dfrac{N_0-N}{N}$ $=\dfrac{N_0}{N}-1$ $=32-1$ $=31$
(d)(i)	$N_0=\dfrac{0.13}{90\times1.66\times10^{-27}}$ $=8.7\times10^{23}$
(ii)	$A_0=\lambda N_0$ $=\left(\dfrac{\ln 2}{28.8\times365\times24\times60\times60}\right)(8.70\times10^{23})$ $=6.64\times10^{14}$ $\approx6.6\times10^{14}$ Bq
(iii)	$P=A\times$ energy released per decay $=(6.64\times10^{14})(0.546\times10^{6}\times1.60\times10^{-19})$
	$P=58$ W

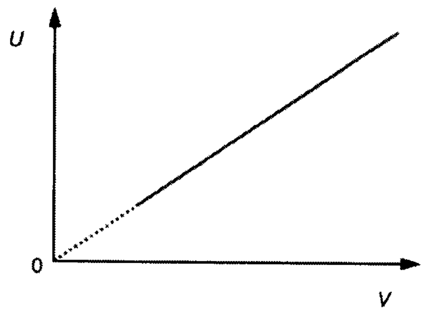
Qn	Suggested Solutions
8(a)	unit of Z = $(\text{unit of } \rho)^a (\text{unit of } \kappa)^b$ $\text{kg m}^{-2}\ \text{s}^{-1} = (\text{kg m}^{-3})^a (\text{m kg}^{-1}\ \text{s}^2)^b$ $= \text{kg}^{a-b}\ \text{m}^{-3a+b}\ \text{s}^{2b}$
	Comparing the powers, $2b = -1$ $b = -\frac{1}{2}$ $a - b = 1$ $a = 1 - \frac{1}{2}$ $= \frac{1}{2}$
(b)(i)	$\frac{I_r}{I_i} = \frac{(Z_{mus} - Z_{bone})^2}{(Z_{mus} + Z_{bone})^2}$ $= \frac{(1.71 - 7.63)^2}{(1.71 + 7.63)^2}$
	$\frac{I_r}{I_i} = 0.402$
(ii)	A significant fraction of the ultrasound beam will not be able to reach the heart as 40% of it gets reflected by the ribs.
(iii)	Liver and kidney
	(It is difficult to detect a boundary if the ultrasound is not reflected from the boundary. $\frac{I_r}{I_i}$ is a minimum when the impedance of the two tissues is as small as possible. i.e. when $Z_1 - Z_2$ is smallest since denominator are similar order of magnitude.)
(c)(i)	$\frac{I}{I_0} = e^{-\mu f x}$ $\frac{1}{2} = e^{-0.23(5.0)x}$
	$x = 0.60$ cm
(ii)	Based on the formula, $I = I_0 e^{-\mu f x}$ For I to be constant, f must decrease for x to increase OR To ensure that the ultrasound beam has a minimum intensity for detection when it enters deeper into the body, it must be attenuated less / its intensity should decrease at a slower rate.
	Low frequency ultrasound waves should be used.

(d)(i)	$\dfrac{I_t}{I_i} = \dfrac{4Z_{PZT}Z_{skin}}{(Z_{PZT}+Z_{skin})^2}$ $= \dfrac{4(30\times10^5)(1.7\times10^5)}{(30\times10^5+1.7\times10^5)^2}$
	$\dfrac{I_t}{I_i}\times100\% = 0.203\times100\%$ $= 20.3\%$ $\approx 20\%$ (Shown)
(ii)	$Z_{matching\ layer} = \sqrt{Z_{PZT}Z_{skin}}$ $= \sqrt{(30\times10^5)(1.7\times10^5)}$ $= 7.14\times10^5\ \text{g cm}^{-2}\ \text{s}^{-1}$
	$\dfrac{I_t}{I_i} = \dfrac{4Z_{PZT}Z_{matching\ layer}}{(Z_{PZT}+Z_{matching\ layer})^2}$ $= \dfrac{4(30\times10^5)(7.14\times10^5)}{(30\times10^5+7.14\times10^5)^2}$ $= 0.621$
	$\dfrac{I_t}{I_i} = \dfrac{4Z_{matching\ layer}Z_{skin}}{(Z_{matching\ layer}+Z_{skin})^2}$ $= \dfrac{4(7.14\times10^5)(1.7\times10^5)}{(7.14\times10^5+1.7\times10^5)^2}$ $= 0.621$
	(Since $P = IA$, efficiency is proportional to the ratio of intensities.) efficiency $= 0.621^2\times100\%$ $= 38.6\%$ $\approx 39\%$
(iii)	thickness $= \dfrac{1}{4}\lambda$ $= \dfrac{1}{4}\left(\dfrac{v}{f}\right)$ $= \dfrac{1}{4}\left(\dfrac{2500}{5.0\times10^6}\right)$ $= 1.25\times10^{-4}$ m

(e)	
(f)	Ionising radiation interacts with water in the cells and break the bonds that hold the water molecule together, producing H and OH free radicals.
	Free radicals combine to form toxic substances like H_2O_2 which can destroy the cell.

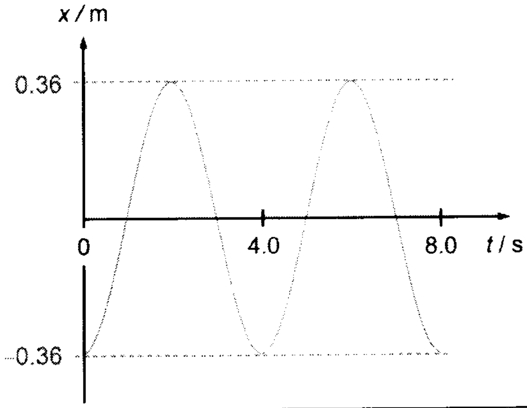
Qn	Suggested Solutions
1(a)	$R=\frac{\rho l}{A}$ $\rho=\frac{RA}{l}$ $=\left(\frac{P}{I^2}\right)\frac{A}{l}$ $=\left(\frac{E}{I^2t}\right)\frac{A}{l}$ unit of $\rho=\frac{\text{unit of } mghA}{\text{unit of } I^2tl}$ $=\frac{(\text{kg})(\text{m s}^{-2})(\text{m})(\text{m}^2)}{\text{A}^2(\text{s})(\text{m})}$
	unit of $\rho=\text{kg m}^3\ \text{s}^{-3}\ \text{A}^{-2}$
(b)	Assume power output of phone charger ~ 10 W Typical USB charging voltage ~ 5 V $I=\frac{P}{V}$ $=\frac{10}{5}$ $=2$ A
(c)	$R=\frac{V}{I}$ $=\frac{5.02}{0.038}$ $=132.105\ \Omega$
	$\frac{\Delta R}{R}=\frac{\Delta V}{V}+\frac{\Delta I}{I}$ $\frac{\Delta R}{132.105}=\frac{0.01}{5.02}+\frac{0.001}{0.038}$ $\Delta R=3.7$ $\approx 4\ \Omega$
	$R\pm\Delta R=(132\pm4)\ \Omega$

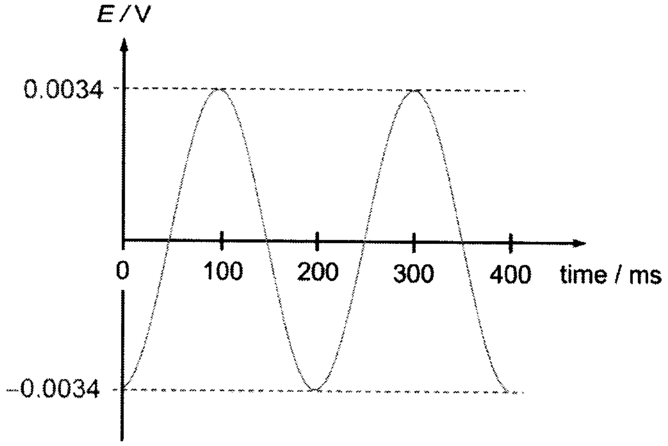
Qn	Suggested Solutions
2(a)	Coulomb's law states that the electric force acting between any two point charges is • directly proportional to the product of the charges and • inversely proportional to the square of their distance apart
(b)	Electric field strength (at a point in an electric field) is equal to the negative electric potential gradient (at that point)
(c)	For potential to be zero, one potential must be positive and the other potential must be negative OR For potential to be zero, the charges must have opposite sign
	For field to be zero, the fields (due to X and Y) must be in opposite directions OR For field to be zero, the charges must have the same sign
	The signs of the charges cannot (simultaneously) be both the same and opposite (so not possible)
(d)(i)	
	• At least six field lines drawn with the • field lines equally spaced near the plates. • Field lines are outside the sphere. • Arrows indicating the direction of the electric field is from the higher potential surface to the lower potential surface (towards the right) • 90° to the surfaces on the sphere and the plates.
(ii)	Charges are free to move in a conductor. In electrostatic equilibrium/for no net movement of charges,
	The component of electric field parallel to the surface of the sphere must be zero. Hence, the potential difference at points on the surface of the charge is zero and the potentials at K and L are equal.
(iii)	$V_K = \frac{900}{2}$ $= 450$ V

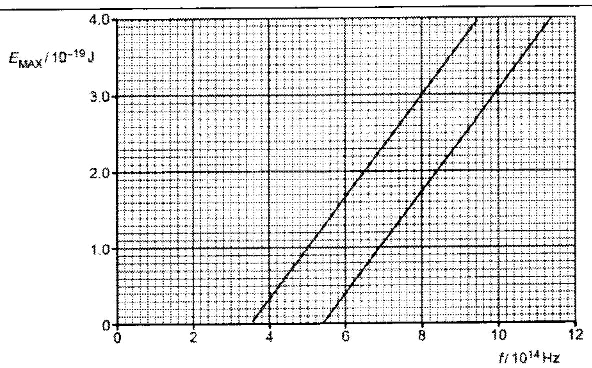
Qn	Suggested Solutions
3(a)	The internal energy U of a system is the sum of a random distribution of potential and kinetic energies of the atoms/molecules/particles in the system.
(b)	⅓: molecules move randomly in three dimensions (not one) so the mean square speed is any one direction is ⅓ of the mean square speed
	$\langle c^2 \rangle$: molecules have different/a range of speeds so take average of the square of speeds
(c)	$p=\frac{1}{3}\rho\langle c^2\rangle$ $p=\frac{1}{3}\left(\frac{Nm}{V}\right)\langle c^2\rangle$ $pV=\frac{1}{3}Nm\langle c^2\rangle$ $\frac{3}{2}pV=\frac{1}{2}Nm\langle c^2\rangle=E_k$
	Using the ideal gas equation of state, $\frac{3}{2}NkT=E_k$
	For an ideal gas, there is no intermolecular forces of attractions so it has no microscopic potential energy. $U=E_k$ Hence, $U \propto T$
(d)(i)	$pV=nRT$ $n=\frac{pV}{RT}$ $=\frac{(2.0\times10^5)(0.26)}{(8.31)(273.15+20)}$ $=21$ mol
	$N=nN_A$ $=(21.34)(6.02\times10^{23})$ $=1.3\times10^{25}$
(ii)	$U=\frac{3}{2}NkT$ $=\frac{3}{2}(1.285\times10^{25})(1.38\times10^{-23})(273.15+20)$ $=7.80\times10^4$ J
(e)	 Since $U \propto T$ and for constant p, $V \propto T$, therefore $U \propto V$ and it will be a straight line.

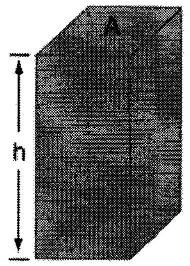
(f)	$\Delta U = Q + W$ For a constant pressure process with an increase in temperature, negative work is done on gas. $Q = \Delta U - W$, where W is negative.
	At constant volume, no work is done on gas. $Q = \Delta U$
	Hence, the heat supplied to raise the temperature by 1 kelvin ($C = Q / \Delta T$) will be higher for the constant pressure process. C_p will be higher than C_v.

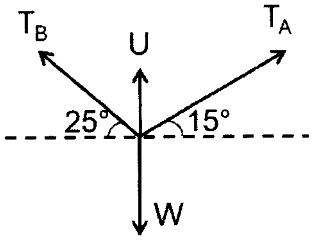
Qn	Suggested Solutions
4(a)	$mg = kx_0$
(b)	Take the downward direction as positive. Resultant force with extension below equilibrium point, $F_R = mg - k(x_0 + x)$ where x_0 is the extension at equilibrium.
	By Newton's second law, $mg - k(x_0 + x) = ma$ $kx_0 - kx_0 - kx = ma$ since $mg = kx_0$ $a = -\frac{k}{m}x$ (Shown)
	OR
	Define upwards as positive $-mg + k(x_0 + x) = ma$
	$-kx_0 + kx_0 + kx = ma$ $a = \frac{k}{m}x$ Since a and x are opposite in direction, $a = -\frac{k}{m}x$
(c)(i)	From graph, $T = 4.0$ s $f = \frac{1}{T} = \frac{1}{4.0}$
	$f = 0.25$ Hz
(ii)	Comparing $a = -\omega^2 x$ and $a = -\frac{k}{m}x$, $\omega^2 = \frac{k}{m}$ $4\pi^2(0.25)^2 = \frac{28}{m}$
	$m = 11.3$ kg
(iii)	Max $E_k = \frac{1}{2}mv_o^2$ $1.8 = \frac{1}{2}(11.3)v_o^2$ $v_0 = 0.564$ ≈ 0.56 m s^{-1}

(iv)	$v_0 = \omega x_0$ $x_0 = \dfrac{v_0}{\omega}$ $= \dfrac{0.564}{2\pi(0.25)}$ $= 0.359$ ≈ 0.36 m
(d)	

Qn	Suggested Solutions
5(a)	Faraday's law states that the magnitude of the induced e.m.f. in a conductor is directly proportional to the rate of change of magnetic flux linkage experienced by the conductor.
(b)	Magnetic flux density in the solenoid is constant. Since the cross sectional area and number of turns of coil C remains the same, the magnetic flux linkage is constant.
(c)(i)	$\omega = \frac{2\pi}{T}$ $T = \frac{2\pi}{\omega}$ $= \frac{2\pi}{10\pi}$
	$T = 0.20$ s $= 200$ ms (Shown)
(ii)	$B_{max} = \mu_0 n I_{max}$ $= (4\pi \times 10^{-7})(4000)(4.8)$ $= 0.024127$ T
	$\Phi_{max} = NB_{max}A\cos 0°$ $= (71)(0.024127)(0.64 \times 10^{-4})$
	$\Phi_{max} = 1.096 \times 10^{-4}$ Wb $= 1.1 \times 10^{-4}$ Wb (Shown)
(iii)	$\Phi = NBA\sin(\omega t)$ $= NA(\mu_0 n I_0)\sin(\omega t)$ $= \Phi_0 \sin(\omega t)$ $\varepsilon = -\frac{d\Phi}{dt} = -\omega\Phi_0\cos(\omega t)$
	$\varepsilon_{max} = \omega\Phi_0$ $= (10\pi)(1.1 \times 10^{-4})$
	$\varepsilon_{max} = 0.0034$ V
(iv)	

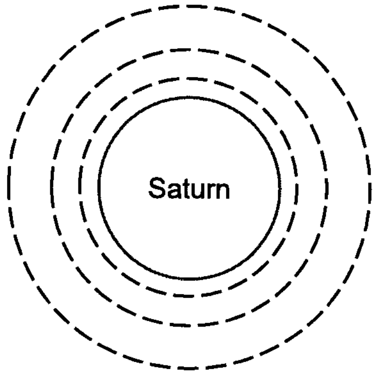
Qn	Suggested Solutions
6(a)	Any two of the following three:
	1. Existence of Threshold Frequency
	Below a certain frequency of the incident radiation, there is no value of maximum kinetic energy, hence no electrons are emitted.
	Energy of radiation is quantised, and if lower than the work function, no electrons will be emitted.
	2. Stopping potential is dependent on frequency but not on intensity.
	For the same intensity of incident light, the higher-frequency light has a larger stopping potential.
	Energy of radiation is quantised and increases so maximum kinetic energy of photoelectrons is higher.
	OR
	For the same frequency of incident light, an increase in the intensity causes the photocurrent to increase but does not affect the stopping potential.
	Energy of radiation is quantised and for same frequency of light, the maximum kinetic energy of photoelectrons does not change.
	3. No Time Lag
	Emission of photoelectrons take place instantly/without a time lag.
	One electron absorbs one photon, with the energy transfer taking place in an instant.
(b)(i)	$hf = hf_o + \text{KE}_{max}$ $\text{KE}_{max} = hf - hf_o$ gradient $= h$ $h = \dfrac{(4.00-0)\times10^{-19}}{(11.4-5.4)\times10^{14}}$
	$h = 6.67\times10^{-34}$ J s
(ii)	$\Phi = hf_o$ $=(6.667\times10^{-34})(5.4\times10^{14})$
	$\Phi = \dfrac{(3.6\times10^{-19})}{(1.6\times10^{-19})}$ eV $= 2.25$ eV
(c)	 The gradient remains the same.
	Since the work function is lower, the threshold frequency increases, the graph is shifted to the left.

<table>
<tr><th>Qn</th><th>Suggested Solutions</th></tr>
<tr><td>7(a)</td><td>The weight of the fluid column
$W = mg$
$= \rho V g$
$= \rho(Ah)g$
where A is the cross-sectional area of the fluid column, V is the volume of fluid above the point

</td></tr>
<tr><td></td><td>The hydrostatic pressure,
$p = \dfrac{F}{A}$
$= \dfrac{\rho A h g}{A}$
$= \rho g h$</td></tr>
<tr><td>(b)(i)</td><td>As pressure increases with depth and $F = PA$,</td></tr>
<tr><td></td><td>the upward force acting on the bottom surface of the sphere is greater than the downward force acting on the top surface.</td></tr>
<tr><td></td><td>This leads to a resultant upward force exerted by the seawater on the sphere (upthrust).</td></tr>
<tr><td>(ii)</td><td>$V_{displaced} = V_{chest}$
$= 2.0 \times 1.50 \times 0.40$
$= 1.2 \text{ m}^3$</td></tr>
<tr><td></td><td>$U = \rho V g$
$= (1030)(1.2)(9.81)$
$= 12125$
$\approx 1.2 \times 10^4 \text{ N}$</td></tr>
<tr><td>(iii)</td><td>$W_{chest} = \rho_{chest} V g$
$= (1800)(1.2)(9.81)$
$= 21190$
$\approx 2.1 \times 10^4 \text{ N}$</td></tr>
</table>

(iv)	
	$\Sigma F_x = 0$ $T_A \cos 15° = T_B \cos 25°$ $T_A = 0.938 T_B \cdots\cdots\cdots\cdots (1)$
	$\Sigma F_y = 0$ $T_A \sin 15° + T_B \sin 25° + U = W$ $T_A \sin 15° + T_B \sin 25° + 1.21 \times 10^4 = 2.12 \times 10^4 \cdots\cdots\cdots (2)$
	$T_A = 1.28 \times 10^4$ N
	$T_B = 1.36 \times 10^4$ N
(c)(i)	$F_d = kv^2$ $= (3.5 \times 10^3)(4.5)^2$ $= 70875$ $\approx 7.09 \times 10^4$ N
	Constant velocity means net force = 0 N $F_{thrust} = F_d$ $= 7.09 \times 10^4$ N
(ii)	$P = \frac{E}{t}$ $= \frac{Fs}{t}$ $= Fv$
	$P = F_{thrust} v$ $= (70875)(4.5)$ $= 3.19 \times 10^5$ W
	$\eta = \frac{\text{useful output power}}{\text{input power}} \times 100\%$ $= \frac{3.19 \times 10^5}{0.50 \times 10^6} \times 100\%$ $= 63.8\%$ $\approx 64\%$

(d)(i)	F_{net} = force removed $= (200)(9.81)$ $= 1962$ N
	total mass = mass of submarine + mass of box $= (3600 - 200) + (1800)(1.2)$ $= 5560$ kg
	$\Sigma F = ma$ $1962 = (5560)a$ $a = 0.353$ m s^{-2}
(ii)	Due to the acceleration, speed increases which causes drag force to increase until
	drag force is equal to the difference between upthrust and the reduced weight. OR Net upward force and acceleration becomes zero. (The submarine then moves at a constant "terminal velocity".)

Qn	Suggested Solutions
8(a)	A *geostationary orbit* is one where the satellite will remain in the same position in the sky relative to the Earth's surface.
(b)(i)	angular velocity $= \frac{v}{r}$ $= \frac{2.26\times10^4(2)}{1.49\times10^8}$ $= 3.03356\times10^{-4}$ $= 3.03\times10^{-4}$ rad s^{-1} (3sf)
(ii)	$T = \frac{2\pi}{\omega}$ $= \frac{2\pi}{3.03356\times10^{-4}}$ $= 20712$ s ≈ 5 h 45 min
	Since orbital period of particle is not equal to the rotational period of Saturn (10 h and 14 min), the particle is not in a stationary orbit.
(iii)	Gravitational force of Saturn provides centripetal force.
	$\frac{GMm}{r^2} = mr\omega^2$
	$r^3\omega^2 = GM$
(iv)	$M = \frac{r^3\omega^2}{G}$ $= \frac{(0.745\times10^8)^3(3.03356\times10^{-4})^2}{6.67\times10^{-11}}$
	$= 5.70490\times10^{26}$
	$= 5.7\times10^{26}$ kg (2sf) (shown)
(c)(i)	*Gravitational potential* at a point in a gravitational field is defined as the work done per unit mass by an external agent
	in bringing a small test mass from infinity to that point, without producing any acceleration.

(ii)	
(iii)	To escape Saturn's gravitational field, the particle must gain GPE and reach infinity with KE ≥ 0. OR Applying conservation of energy, Gain in GPE = Loss in KE $GPE_\infty - GPE_i = KE_i - KE_\infty$
	$GMm\left(\frac{1}{r_i}-\frac{1}{r_\infty}\right)=\frac{1}{2}m\left(v_i^2-v_\infty^2\right)$ $v_i=\sqrt{(2\times 6.67\times 10^{-11}\times 5.7\times 10^{26})\left(\frac{1}{0.745\times 10^8}-0\right)+0}$
	$v_i = 3.19475\times 10^4$ additional v required $= 3.19475\times 10^4 - 2.26\times 10^4$ $= 9347.5$ $= 9350$ m s^{-1} (3sf)
(d)(i)	Let the distance be x. $\frac{GM_T}{x^2}=\frac{GM_S}{(1.22\times 10^9 - x)^2}$
	$\frac{1.4\times 10^{23}}{x^2}=\frac{5.7\times 10^{26}}{(1.22\times 10^9 - x)^2}$ $(1.22\times 10^9 - x)\sqrt{1.4\times 10^{23}} = 5.7\times 10^{26} x$
	$x = 1.88249\times 10^7$ $= 1.88\times 10^7$ m (3sf)

(ii)	Taking rightwards to be positive,