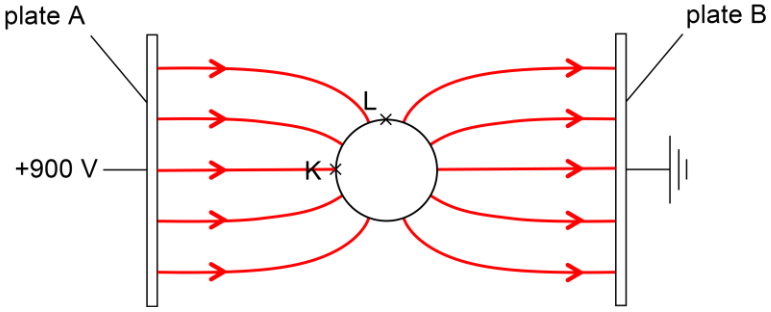
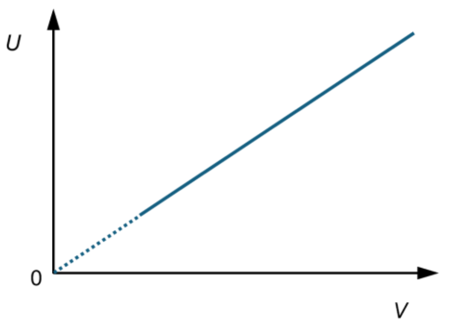
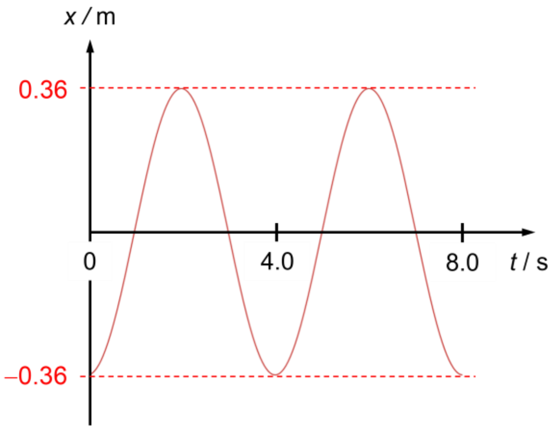
Qn	Suggested Solutions
1(a)	$R = \dfrac{\rho l}{A}$ $\rho = \dfrac{RA}{l}$ $= \left(\dfrac{P}{I^2}\right)\dfrac{A}{l}$ $= \left(\dfrac{E}{I^2 t}\right)\dfrac{A}{l}$ unit of $\rho = \dfrac{\text{unit of } mghA}{\text{unit of } I^2 t l}$ $= \dfrac{(\text{kg})(\text{m s}^{-2})(\text{m})(\text{m}^2)}{\text{A}^2(\text{s})(\text{m})}$
	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 $I = \dfrac{P}{V}$ $= \dfrac{10}{5}$ $= 2$ A
(c)	$R = \dfrac{V}{I}$ $= \dfrac{5.02}{0.038}$ $= 132.105\ \Omega$
	$\dfrac{\Delta R}{R} = \dfrac{\Delta V}{V} + \dfrac{\Delta I}{I}$ $\dfrac{\Delta R}{132.105} = \dfrac{0.01}{5.02} + \dfrac{0.001}{0.038}$ $\Delta R = 3.7$ $\approx 4\ \Omega$
	$R \pm \Delta R = (132 \pm 4)\ \Omega$

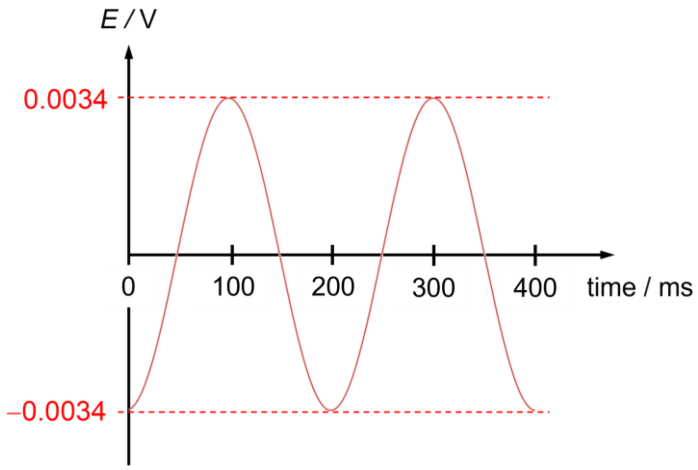
Qn	Suggested Solutions
2(a)	Coulomb's law states that the electric force acting between any two point charges is • directly proportional to the product of the charges and • inversely proportional to the square of their distance apart
(b)	Electric field strength (at a point in an electric field) is equal 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

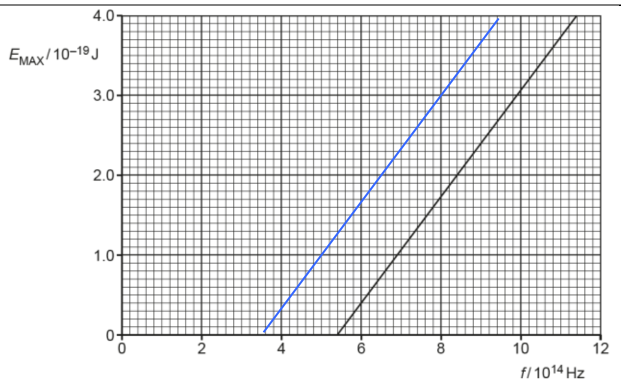
Qn	**Suggested Solutions**
3(a)	The internal energy *U* of a system is the sum of a random distribution of potential and kinetic energies of the atoms/molecules/particles in the system.
(b)	⅓: molecules move randomly in three dimensions (not one) so the mean square speed is any one direction is ⅓ of the mean square speed
	$<c^2>$: 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)	$pV = nRT$ $n = \frac{pV}{RT}$ $= \frac{(2.0\times10^5)(0.26)}{(8.31)(273.15+20)}$ $= 21\text{ mol}$
	$N = nN_A$ $= (21.34)(6.02\times10^{23})$ $= 1.3\times10^{25}$
(ii)	$U = \frac{3}{2}NkT$ $= \frac{3}{2}(1.285\times10^{25})(1.38\times10^{-23})(273.15+20)$ $= 7.80\times10^4\text{ J}$
(e)	 Since $U \propto T$ and for constant *p*, $V \propto T$, therefore $U \propto V$ and it will be a straight line.

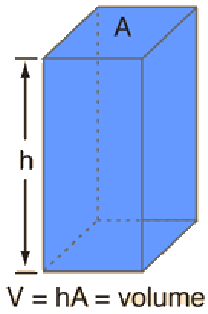
(f)	$\Delta U = Q + W$ For a constant pressure process with an increase in temperature, negative work is done on gas. $Q = \Delta U - W$, where W is negative.
	At constant volume, no work is done on gas. $Q = \Delta U$
	Hence, the heat supplied to raise the temperature by 1 kelvin ($C = Q / \Delta T$)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

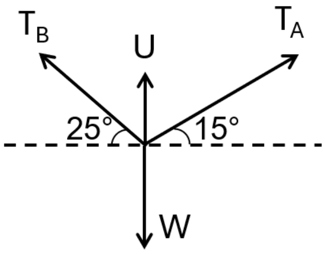
Qn	Suggested Solutions
4(a)	$mg = kx_0$
(b)	Take the downward direction as positive. Resultant force with extension below equilibrium point, $F_R = mg - k(x_0 + x)$ where x_0 is the extension at equilibrium.
	By Newton's second law, $mg - k(x_0 + x) = ma$ $kx_0 - kx_0 - kx = ma$ since $mg = kx_0$ $a = -\frac{k}{m}x$ (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)	

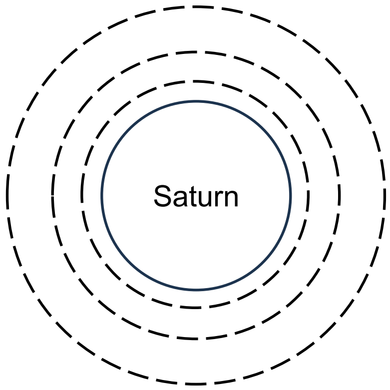
Qn	Suggested Solutions
6(a)	Any two of the following three:
	1. Existence of Threshold Frequency
	Below a certain frequency of the incident radiation, there is no value of maximum kinetic energy, hence no electrons are emitted.
	Energy of radiation is quantised, and if lower than the work function, no 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)	$hf = hf_o + \text{KE}_{\text{max}}$ $\text{KE}_{\text{max}} = hf - hf_o$ gradient $= h$ $h = \dfrac{(4.00-0)\times 10^{-19}}{(11.4-5.4)\times 10^{14}}$
	$h = 6.67 \times 10^{-34}$ J s
(ii)	$\Phi = hf_o$ $= (6.667\times 10^{-34})(5.4\times 10^{14})$
	$\Phi = \dfrac{(3.6\times 10^{-19})}{(1.6\times 10^{-19})}$ 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.

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

(iv)	
	$\Sigma F_x = 0$ $T_A \cos 15° = T_B \cos 25°$ $T_A = 0.938 T_B \cdots\cdots\cdots\cdots(1)$
	$\Sigma F_y = 0$ $T_A \sin 15° + T_B \sin 25° + U = W$ $T_A \sin 15° + T_B \sin 25° + 1.21\times10^4 = 2.12\times10^4 \cdots\cdots\cdots(2)$
	$T_A = 1.28\times10^4$ N
	$T_B = 1.36\times10^4$ N
(c)(i)	$F_d = kv^2$ $= (3.5\times10^3)(4.5)^2$ $= 70875$ $\approx 7.09\times10^4$ N
	Constant velocity means net force = 0 N $F_{thrust} = F_d$ $= 7.09\times10^4$ N
(ii)	$P = \frac{E}{t}$ $= \frac{Fs}{t}$ $= Fv$
	$P = F_{thrust} v$ $= (70875)(4.5)$ $= 3.19\times10^5$ W
	$\eta = \frac{\text{useful output power}}{\text{input power}} \times 100\%$ $= \frac{3.19\times10^5}{0.50\times10^6}\times100\%$ $= 63.8\%$ $\approx 64\%$

(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 $\geq$ 0. OR Applying conservation of energy, Gain in GPE = Loss in KE $\mathrm{GPE}_{\infty} - \mathrm{GPE}_{\mathrm{i}} = \mathrm{KE}_{\mathrm{i}} - \mathrm{KE}_{\infty}$
	$GMm\left(\frac{1}{r_i} - \frac{1}{r_\infty}\right) = \frac{1}{2}m\left(v_i^2 - v_\infty^2\right)$ $v_i = \sqrt{(2\times 6.67\times 10^{-11}\times 5.7\times 10^{26})\left(\frac{1}{0.745\times 10^{8}} - 0\right) + 0}$
	$v_i = 3.19475\times 10^{4}$ 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,