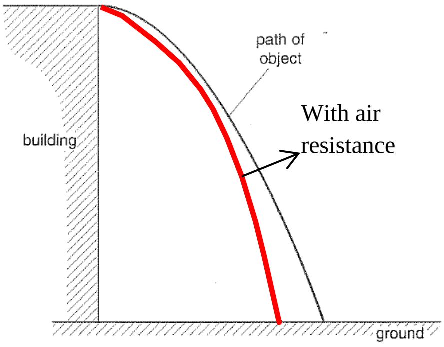
1	(a)	(i) The horizontal component of the velocity will be constant since there is no horizontal acceleration.
		(ii) The vertical component of the velocity will increase from uniformly from zero at a constant rate of *g* or 9.81m s^{-2} since there is vertical gravitational acceleration.
	(b)	(i) The horizontal component of the velocity will decrease non-uniformly with time at a bigger initial rate of decrease.
		(ii) The vertical velocity will increase at an initial rate of *g* (or 9.81 m s^{-2}). However, the final vertical velocity component will be smaller because the gravitational force downwards will now be opposed by air resistance upwards.
	(c)	
2	(a)	(i) The *radian* is the angle subtended by an arc of length equal to the radius of a circle i.e. $\theta = s/r$.
		(ii) For an object in simple harmonic oscillation, *angular frequency* ω is the characteristic constant of the oscillator given by $\omega = 2\pi f$, where *f* is the natural frequency of the oscillator.
	(b)	(i) The total energy of the sphere is equivalent to its initial gravitational potential energy at its highest point before release. Hence, $E_{tot} = mg\Delta h = (0.120)(9.81)(0.0040) =$ **<u>4.7 x 10⁻³ J</u>**
		(ii) $E_{tot} = ½\, m\omega^2 x_o^2 = ½\,(0.120)(\omega^2)(0.080^2)$ $\omega = 3.50 = 2\pi f$, i.e. $f = \frac{1}{2\pi}\sqrt{\frac{2E_{tot}}{m{x_0}^2}} = \frac{1}{2\pi}\sqrt{\frac{2(4.7\text{x}10^{-3})}{(0.120)(8.0\text{x}10^{-2})^2}}$ = **0.56 Hz**
3	(a)	The First Law of Thermodynamics states that the internal energy *U* of a system depends on its state and the increase in internal energy ΔU is equal to sum of the heat supplied ΔQ and work done ΔW on the system; i.e. $\Delta U = \Delta Q + \Delta W$.
	(b)	(i) Using $pV = nRT$ for state X, the amount of gas, $n = \frac{pV}{RT} = \frac{2.4\text{x}10^5\text{x}5.0\text{x}10^{-4}}{8.31\text{x}290} =$ **0.0498 mol**
		(ii) 1 Work done ***on*** the system in the expansion from X to Y is given by $\Delta W = -(2.4 \text{ x } 10^5)([14.4 - 5.0]\text{x}10^{-4}) =$ **-226J** . Alternatively, work done ***by*** the system is 226 J.

(ii) 2 The change in internal energy for one complete cycle XYZX is **zero** as the system returns to its original state.

(iii)

change	work done on gas/J	heating supplied to gas/J	increase in internal energy/J
X → Y	**- 226**	+ 570	**+344**
Y → Z	+ 540	0	**+ 540**
Z → X	0	**- 884**	**- 884**

4 (a) The principle states that when waves of the same kind meet at a point in space, the resultant wave displacement is given by the vector sum of the individual wave displacements at that point.

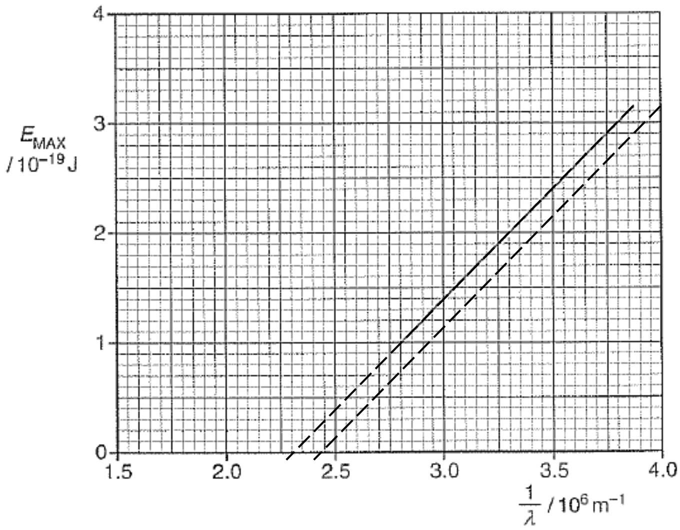
(b) (i) The phase difference between the two waves arriving at point P is

$$\Delta\phi = \frac{\Delta t}{T} x 2\pi = \frac{7}{44} x 2\pi = 1.0 \text{ rad} = \mathbf{57.3^o}$$

(ii) The bright fringe closest to point P has resultant amplitude, A_b = 3.4 + 0.6 = 4.0 units. The dark fringe closest to point P has resultant amplitude A_d = 3.4 - 0.6 = 2.8 units. Intensity of light at a point is directly proportional to the square of the amplitude. Hence, $\frac{\text{the intensity of the dark fringe}}{\text{intensity of the bright fringe}} = \frac{2.8^2}{4.0^2} = \mathbf{0.49}$

5 (a) $E_{max} = hf - \phi = hf - hf_0 = hc(1/\lambda - 1/\lambda_o)$

(b) (i) The intercept at the $1/\lambda$ axis will give the value of $1/\lambda_o$ where E_{max} is zero. From the graph



$1/\lambda_o = 2.3 \times 10^6 \text{ m}^{-1}$. Thus, λ_o = $\mathbf{4.35 \times 10^{-7}}$ **m**

		(ii) The gradient of the graph is the value of the *hc*. Thus, $hc = \frac{2.90\text{x}10^{-19}}{(3.75-2.30)\text{x}10^{6}} \Rightarrow \boldsymbol{h} = \mathbf{6.7x10^{-34}}$ **J s**
	(c)	The sketch is shown as the dotted line in (b) (i). A higher value of work function corresponds to a shorter threshold wavelength of λ_o with a bigger horizontal intercept value of $1/\lambda_o$.
6	(a)	(i) A *field of force* refers to a region of space where an object or particle will experience a force due to the specific property possessed by the object or particle, e.g. mass or charge of the object.
		(ii) The charged particle may be moving at a non-zero angle to a magnetic field, in which case it will experience a magnetic force by virtue of its charge. It may also be in a gravitational field such that, whether it is stationary or moving, it will experience a gravitational force by virtue of its mass.
	(b)	(i) The two regions are within the metal spheres where the field should be zero under electrostatic equilibrium conditions.
		(ii) 1. Radius of sphere A, $\boldsymbol{r_A}$ **= 4.0 cm**; and radius of sphere B, $\boldsymbol{r_B}$ **= 2.0 cm**. 2. The two spheres have charges of opposite sign. The graph shows that the electric field is always positive between the two spheres, implying that the direction of the electric field is constant (always pointing towards the right). From the definition of the electric field, this means that the left sphere is positively charged while the right sphere is negatively charged. (The above point is sufficient as the answer, but the following additional point is also acceptable, though there is not enough space to write it down.) Furthermore, the graph shows that the electric field is never zero along the line joining the two spheres. If the charges on the two spheres are of the same sign, their electric fields would be opposite in direction along the line between the spheres, and so there will be a point where the resultant electric field is zero. Hence, the spheres must have charges of opposite signs. (Alternate explanation: The two spheres have charges of opposite sign and of different magnitudes. The resultant field in the region between them is given by the vector sum of the two fields contributed by each. The individual fields decrease in magnitude inversely to the square of distance from the centre of the sphere, resulting in the smallest magnitude in between them.)
		(iii) Note: the electric field is practically constant in the region from x = 16 cm to x = 21 cm. 1 The energy gain is given by the approximate work done by the electric force given by $W = F_E\, \Delta x = (qE) \text{ x } \Delta x$ = (3 x 1.6 x10^{-19})(1.2 x 10^5)(0.210 – 0.160) = **2.88 X 10^{-15} J**

		2 At x = 25.0 cm, E_x = 3.0 x 10^5 V m^{-1}. The acceleration of the nucleus at this point is given by $a = F/m = (qE/m)$= (3 x 1.6 x 10^{-19} x 3.0 x 10^5)/(7 x 1.67 x 10^{-27}) = **1.23 x 10^{13} m s^{-2}** 3 Acceleration $\propto$ electric field. The acceleration will decrease sharply at first and subsequently more gently from x = 4.0 cm to a minimum value around x = 18.0 cm. Thereafter, it will increase gently at first and more sharply subsequently up to x = 28.0 cm. The acceleration is in the same direction throughout.
7	(a)	(i) The resistance R of a wire is defined as the ration of the potential difference V across it over the current I passing through it, i.e. $R = V/I$.
		(ii) The resistivity of a wire is the characteristic property of the material of the wire given by $\rho = \frac{RA}{L}$ where R, A and L are the resistance, cross-sectional area and length of the wire respectively.
	(b)	(i) The total circuit resistance, $R_{tot} = (0.10 + R_{coil})$= 6.0/1.2. Hence, the resistance of the coil, R_{coil} = 5.0 – 0.1 = **4.9 Ω**
		(ii) The resistance of the coil is given by $R_{coil} = \frac{\rho N l}{A} = 4.9$, where N is the number of turns of the coil and l is the length one coil turn. Thus, the number of turns of the coil is given by $N = \frac{R_{coil} A}{\rho l} = \frac{(4.9)(\pi \text{ x } 0.0003^2)}{(1.7\text{x}10^{-8})(\pi \text{ x } 0.220)} = \mathbf{118}$
	(c)	$B = 0.72(4\pi \text{ x } 10^{-7})\frac{(118)(1.2)}{0.110} = \mathbf{1.2x10^{-3}\ T}$
	(d)	(i) The K.E. of the electron , K is given by $K = eV = \frac{1}{2}\frac{p^2}{m}$. Thus, the momentum p of the electron is given by $p = \sqrt{2meV} = \sqrt{2(9.11\text{x}10^{-31})(1.6\text{x}10^{-19})(250)} = \mathbf{8.54\,x10^{-24}\ N\,s}$
		(ii) For the circular motion of the electron inside the B field, $F_c = F_B$. Hence, $\frac{mv^2}{r} = evB$, or $\frac{p}{r} = eB$. Thus, the radius $r = p/(eB)$ = (8.54 x 10^{-24})/[(1.6 x 10^{-19})(1.2 x 10^{-3}) = **0.044 m**
	(e)	If the electron enters the B field at an oblique angle as shown, its velocity component parallel to the field will cause the electron to move forward along the field lines. The component of the velocity perpendicular to the filed lines will cause it to move in a circular path. The forward and circular motions together will result in the electron moving in a helical path in the field. Since the electron is projected from outside the field, it will describe only half a helix before it exits he field again.
8	(a)	(i) Radioactive decay refers to the process of an unstable nucleus disintegrating with the emission of α, β and/or γ radiation in its attempt to attain a more stable state.
		(ii) The random process refers to a situation where it is not possible to predict

		which nucleus will decay at a given instant of time.
		(iii) The spontaneous emission process implies that no physical or chemical process can control the emission event and rate.
	(b)	(i) The probability per second of the decay is given by the decay constant which is related to the half-life by $\lambda = \ln 2/t_{1/2} = \ln 2/(86.4 \times 365 \times 24 \times 3600)$ = **2.54×10^{-10} s^{-1}**
		(ii) The required power is given by $P = A_oE$, where A_o (= λN_o) is the activity and E being the energy of each emitted α particle. Thus, $P = \lambda N_oE$. Thus, $2400 = (2.54 \times 10^{-10})(N_o)(5.48 \times 10^6 \times 1.6 \times 10^{-19})$. The initial number of active nuclei required, $N_o = 1.08 \times 10^{25}$. The corresponding mass required is $m_o = (N_o)(238\ u)$ = **4.26 kg**
	(c)	(i) The efficiency is given by $\eta = 160/2400 = 0.067$ = **6.7 %**
		(ii) After 3.2 years, the activity will be given by $A = A_0e^{-\lambda t}$. Electrical power is $P' = \eta AE = \eta A_0e^{-\lambda t}E = (\eta e^{-\lambda t})A_0E = (0.067)e^{-(\frac{\ln 2}{86.4}\times 3.2)}(2400) \approx$ **157 W** Alternative: the number of active nuclei remaining will be given by $N = N_o(\frac{1}{2})^x$, where $x = (3.2/86.4) = 0.037$. Hence the effective electrical power generated will become $P' = (\frac{1}{2})^{0.037} \times 0.067 \times 2400 = 157$ W
	(d)	(i) Plutonium-238 has a long half-life compared to Po-201 and will generate electrical power that is relatively constant during the duration of the mission compared with polonium-210, which has a short half life.
		(ii) Pu-238 emits α-particles which are not as penetrating as the β-particles from Str-90. Consequently, the former should be easier to shield and this should improve safety.