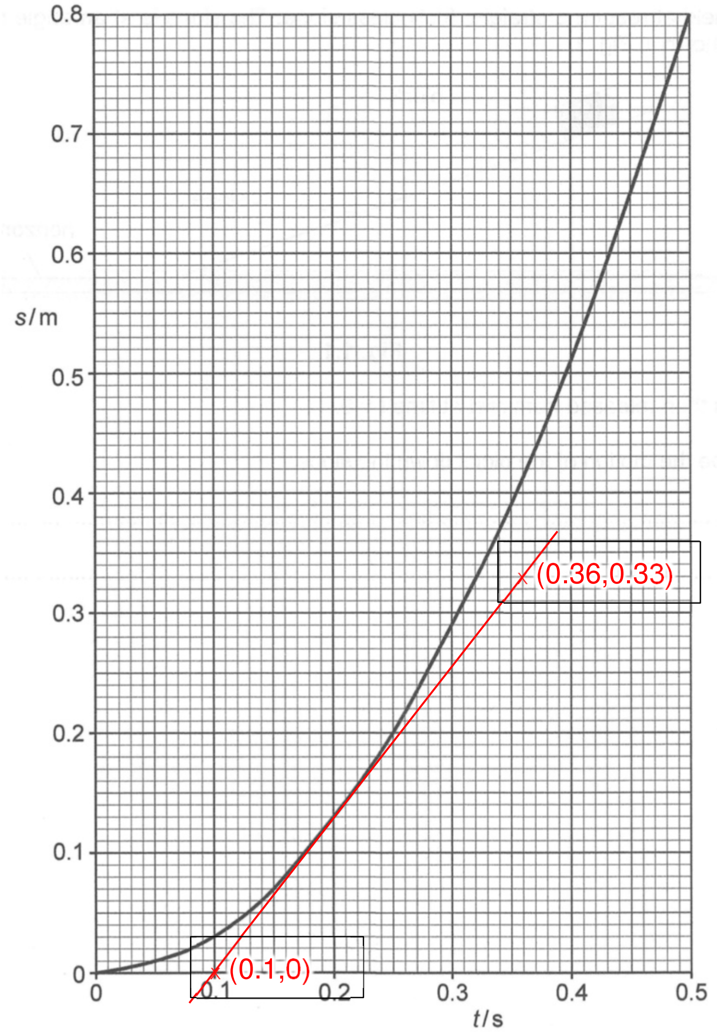
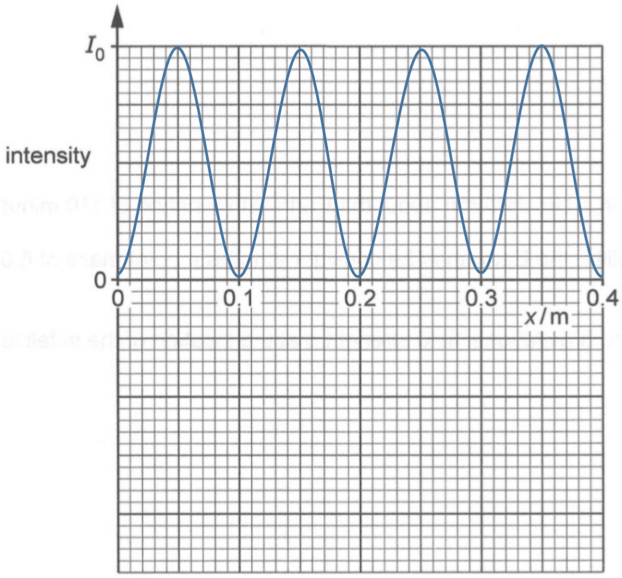
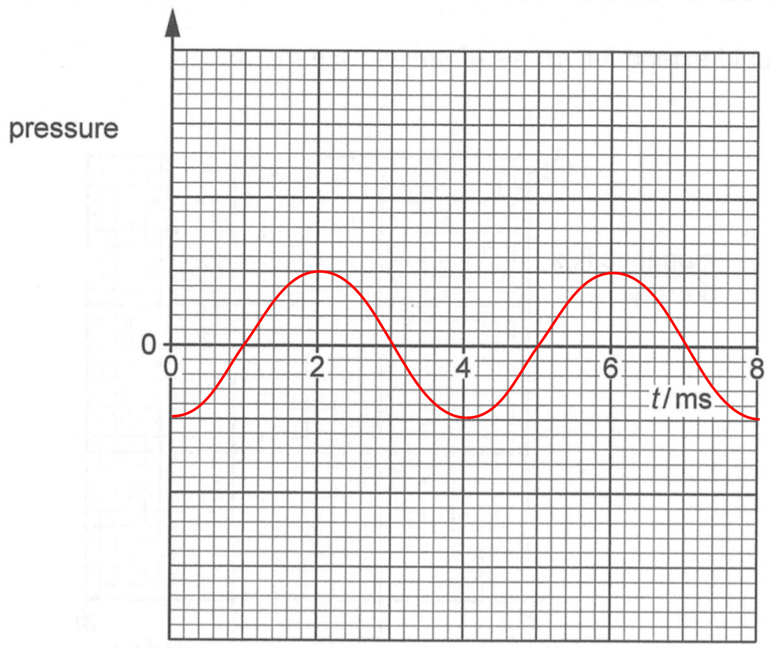
1	**(a)**		The block will accelerate down the slope (with a constant acceleration $a = g\sin\theta$ directed along the slope) with increasing velocity.
1	**(b)**	**(i)**	 Tangent must be drawn accurately at $t = 20$ s. $v = \dfrac{0.33-0}{0.36-0.1} = 1.27 \text{ m s}^{-1}$
1	**(b)**	**(ii)**	Range of acceptable *a* values $a = \dfrac{v-u}{t} = \dfrac{1.27-0}{0.20} = 6.35 \text{ m s}^{-2}$ OR $v^2 = u^2 + 2as$ $(1.27)^2 = 0 + 2a(0.13)$ $a = 6.20 \text{ m s}^{-2}$ OR

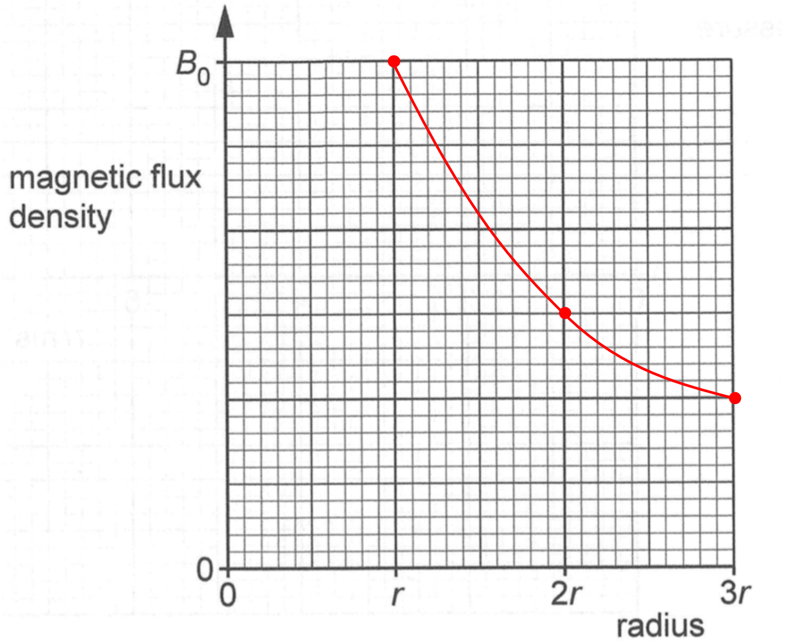
			$s = ut^2 + 0.5at^2$ $0.13 = 0 + 0.5a(0.20)^2$ $a = 6.50\text{ m s}^{-2}$
2	**(a)**		Momentum just before contact with ground = 3.2 N s $E_K = \frac{p^2}{2m} = \frac{(3.2)^2}{2(0.62)} = 8.26\text{ J}$
2	**(b)**		Momentum is a vector and direction has to be taken into account. Based on the graph, downward is positive. Momentum changed from 3.2 N s to −1.8 N s. Time taken is from 0.53 s to 0.68 s. N2L: Net force acting on the ball $= \frac{\Delta p}{\Delta t} = \frac{(-1.8-3.2)}{(0.68-0.53)} = -33.3\text{ N}$ (i.e. 33.3N upward) Magnitude of the average (normal contact) force the ground exerts on the ball = F_{net} + mg = 33.3 + (0.62)(9.81) = 39.4 N (upward)
2	**(c)**		percentage of kinetic energy remaining after each bounce $= \frac{\frac{p_{final}^2}{2m}}{\frac{p_{initial}^2}{2m}} = \left(\frac{1.8}{3.2}\right)^2 = 0.31641$ Let number of bounces before energy drops to less than 5% of initial be N $(0.31641)^N < 0.05$ $N > \frac{\ln 0.05}{\ln 0.31641} = 2.60$ Therefore, 3 bounces before energy drops below 5% of the initial energy.
3	**(a)**		Taking moments about Q, $(F\sin 43°)\left(\frac{2}{3}\text{PQ}\right) = (mg)\left(\frac{1}{2}PQ\cos 58°\right)$ $F = \frac{\frac{3}{4}\cos 58°}{\sin 43°}mg = \frac{3\cos 58°}{4\sin 43°}(2.3\times 9.81) = 13.1\text{ N}$ Comments: studnets have difficulty resolving F and W to obtain the component that was perpendicular to the line PQ.
3	**(b)**		Force F has a horizontal component towards the right while W has no horiztontal component.

			For the system to be in equilibrium, the contact force at Q should have a component directed towards the left to ensure that the sum of the forces in the horiziontal direction must be zero. Hence, contact force at Q needs to be at an angle to the left of the vertical. Comments: studnets have incomplete answres when they only state that F has a horizontal component. Answers were vague when it only talks about the need of forces to balance or cancel out W and F.
4	**(a)**		Newton's law of gravitation: $F=\frac{GMm}{r^2}$ Since gravitational field strength is the gravitational force per unit mass placed at that point: $g=\frac{F}{m}=\frac{GM}{r^2}$
4	**(b)**		Orbit: involves circular motion. Gravitational force provides for centripetal force. $F_g = ma_c$ $\frac{GMm}{r^2}=mr\omega^2$ $\frac{GMm}{r^2}=mr\left(\frac{2\pi}{T}\right)^2$ $\frac{GM}{r^3}=\frac{4\pi^2}{T^2}$ $r=\left[\frac{GMT^2}{4\pi^2}\right]^{\frac{1}{3}}=\left[\frac{6.67\times10^{-11}\times6\times10^{24}\times(110\times60)^2}{4\pi^2}\right]^{\frac{1}{3}}=7614974\,m$ $g=\frac{GM}{r^2}=\frac{6.67\times10^{-11}\times6\times10^{24}}{7614974^2}=6.9\text{ N kg}^{-1}$

4	**(c)**		**Version 1:** Radius of Earth: $g = \frac{GM}{r_E^2} \Rightarrow r_E = \sqrt{\frac{(6.67\times10^{-11})(6\times0^{24})}{9.81}} = 6.39\times10^6$ m Centripetal acceleration near surface of Earth: $a_c = r\omega^2 = (6.39\times10^6)\left(\frac{2\pi}{24\times60\times60}\right)^2 = 0.0338$ m s^{-2} acceleration of free fall $a = g - a_c$ Since the Earth rotates with a very slow angular velocity, the centripetal acceleration of an object at the surface of the Earth is negligible compared to the gravitational field strength. Hence, the acceleration due to free fall is taken as equal to the gravitational field strength. **Version 2:** An object released near surface of the Earth is not in orbit around Earth. The gravitational force on the object is solely providing for acceleration due to free fall. The acceleration due to free fall is the acceleration of a body that is acted on only by the weight. Hence mg = ma and acceleration due to free fall will be equal to gravitational field strength.

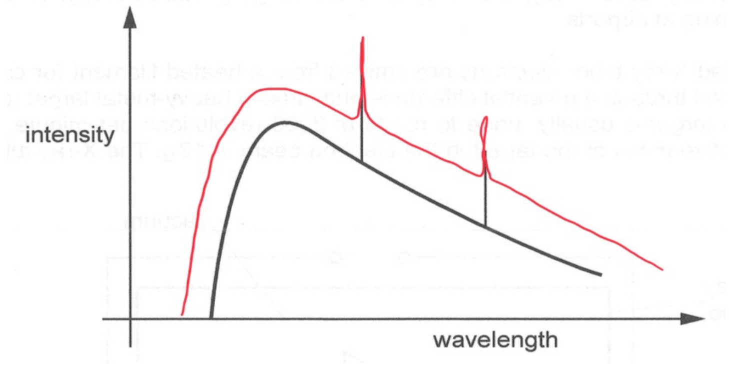
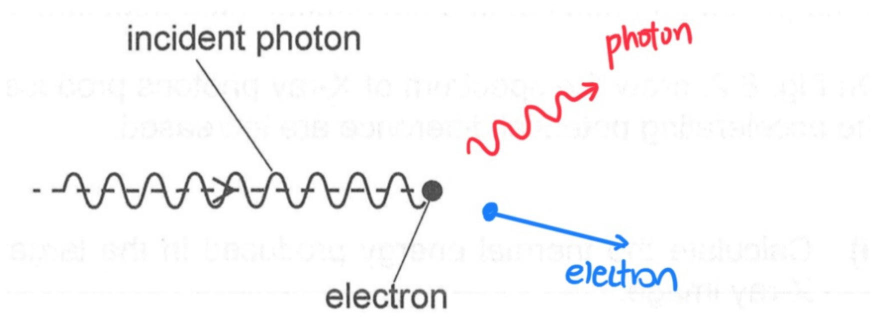
5	**(a)**		$\lambda = \frac{v}{f} = \frac{340}{1700} = 0.200\text{ m}$ Therefore, adjacent nodes are 0.100 m apart, and so are the antinodes. Intensity is proportional to the square of the amplitude, thus the intensity graph is a sin^2 graph. 

5	**(b)**		$T = \frac{1}{f} = \frac{1}{250} = 4.0$ ms Thus every 4 ms the pressure will complete a cycle (rarefaction – compression – rarefaction) We are asked to graph the CHANGE in pressure so there will be increase and decrease of pressure about the equilibrium pressure, so it will be either a sine or cosine graph. 

5	(c)		From formulae list: $B = \dfrac{\mu_0 NI}{2r}$ the graph will be an inversely proportional graph, take note of the values at r, 2r, and 3r. 

6	**(a)**	**(i)**	Voltage across lamp: $V = IR = 0.3 \times 5.0 = 1.5$ V Hence, since e.m.f. = 6.0 V, voltage across 3.0Ω resistor is 4.5V. Total current in the circuit: $I_{\text{total}} = \frac{V}{R} = \frac{4.5}{3.0} = 1.5$ A Hence, current flowing through R must be 1.5 – 0.3 = 1.2 A Given that lamp and R are connected in parallel, the voltage across R is also 1.5 V. $R = \frac{V}{I} = \frac{1.5}{1.2} = 1.25\ \Omega$
6	**(a)**	**(ii)**	Power across lamp: $P_{\text{lamp}} = I^2 R = (0.3)^2 (5.0) = 0.45$ W Total power dissipated in circuit: $P_{\text{total}} = IV = (1.5)(6.0) = 9.0$ W By proportionality, the energy dissipated in lamp: $\frac{E_{\text{lamp}}}{E_{\text{total}}} = \frac{P_{\text{lamp}}}{P_{\text{total}}}$ $\frac{E_{\text{lamp}}}{120} = \frac{0.45}{9.0}$ $E_{\text{lamp}} = 6.0$ J
6	**(a)**	**(iii)**	When the filament is just switched on, it is cold and the resistance of the filament will be low. Hence, the filament with a lower resistance initially will allow higher current to flow. As the filament heats up, its resistance increases with temperature and hence current flow will be reduced.
6	**(b)**		$I = Anvq$ Being connected in series, X and Y have the same current I. $A_X n_X v_X q = A_Y n_Y v_Y q$ $(\pi r_X^2) n_X v_X = (\pi r_Y^2) n_Y v_Y$ $\frac{n_Y}{n_X} = \frac{r_X^2 v_X}{r_Y^2 v_Y} = \left(\frac{1}{2}\right)^2 (3) = 0.75$
7	**(a)**		Charge distribution: Most of the alpha particles were not deflected or deflected by small amounts which shows that the charge was concentrated in an extremely small volume in the middle of the nucleus. Some alpha particles were deflected close to 180° which means that there is a force of repulsion so the nucleus must also be positively charged. Mass distribution: The alpha particles which deflected at a large angle (even up to 180°) means that they collided with an object whose mass is much larger than the alpha particle, which means the mass of the atom is also concentrated in an extremely small volume.

7	**(b)**		Assuming all the kinetic energy is converted to electric potential energy at the point of closest approach: $E_K = \frac{Qq}{4\pi\varepsilon_0 r}$ $r = \frac{(2e)(79e)}{(5.59\times10^6 \times e)(4\pi)(8.85\times10^{-12})} = 4.07\times10^{-14}\text{ m}$
7	**(c)**		${}^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\alpha$ $\text{BE}_{\text{product}} - \text{BE}_{\text{reactant}} = \text{excess energy}$ $4(\text{BE}_{\text{per nucleon},\alpha}) + 218(\text{BE}_{\text{per nucleon,Po}}) - 222(\text{BE}_{\text{per nucleon,Rn}}) = 6.62$ $4(7.08) + 218(\text{BE}_{\text{per nucleon,Po}}) - 222(7.69) = 6.62$ $(\text{BE}_{\text{per nucleon,Po}}) = 7.7316\text{ MeV} = 7.73\text{ MeV}$

8	**(a)**		To ensure that the accelerated electrons reach the target without colliding with air molecules and so not resulting in loss in their kinetic energy.
8	**(b)**		 • lower mininum wavelength • higher intensity peak at a smaller wavelength • characteristic vertical lines at the same wavelength Lower minimum wavelength due to higher energy in the most energetic photon produced (due to higher accelerating voltage giving rise to higher kinetic energy in the incident high energy electrons). Higher intensity across all wavelengths since higher current leads to greater number of electrons per second hitting the target and hence producing higher number of photons across entire range of wavelengths.
8	**(c)**	**(i)**	Thermal energy is 99% of the electrical energy provided. $E = 0.99\times(IVt) = 0.99\times\left(0.12\times 65\times 10^{3}\times 1.1\right) = 8.49\times 10^{3}$ J
8	**(c)**	**(ii)**	$E = mc\Delta\theta$ $8494.2 = 0.012\times 130\times\Delta\theta$ $\Delta\theta = 5400$ °C
8	**(c)**	**(iii)**	(Note: The increase in temperature for a stationary fixed 12g target will be 5400 °C which exceeds the melting point of Tungten.) When the anode is rotated, the heating effect takes place over the entire anode that is more massive than that of the effective 12g target area. This leads to lower rise in temperature of the entire anode so that it does not melt during the process.
8	**(d)**	**(i)**	

8	**(d)**	**(ii)**	As the photon loses some of its initial energy to the electron, the wavelength of the photon will increase. This is because energy of the photon is inversely proportional to the wavelength of the photon.
8	**(d)**	**(iii)**	Since the photons from the Compton scattering are not from the intended straight line path, it will create a blurring effect / decrease the contrast of the x-ray image.
8	**(e)**		$\dfrac{\text{attenuation of X-rays in bone}}{\text{attenuation of X-ray in soft tissue}} = \left(\dfrac{Z_{\text{bone}}}{Z_{\text{soft tissue}}}\right)^3 = \left(\dfrac{14}{7}\right)^3 = 8$
8	**(f)**		Intensity $I = I_0 e^{-\mu x}$ $\frac{1}{2} I_0 = I_0 e^{-\mu x_{1/2}}$ $\ln 2 = \mu x_{1/2}$ $x_{1/2} = \dfrac{\ln 2}{\mu}$
8	**(g)**		Lower intensity of X-ray radiation can be used, hence lesser risk of side-effects from X-ray exposure.
8	**(h)**		By consuming barium solution, the digestive system will have a higher average Z-number and hence a stronger attenuation effect on the X-ray radiation. This will increase the contrast of the image as the digestive system will have a stronger attenuation of X-ray compared to the surrounding tissues.
8	**(i)**		Longer duration of time that the patient is exposed to X-ray radiation, resulting in higher amount of X-ray that the patient is being exposed to. This is due to the need to take multiple X-ray exposures at varying directions to produce a 3D image.