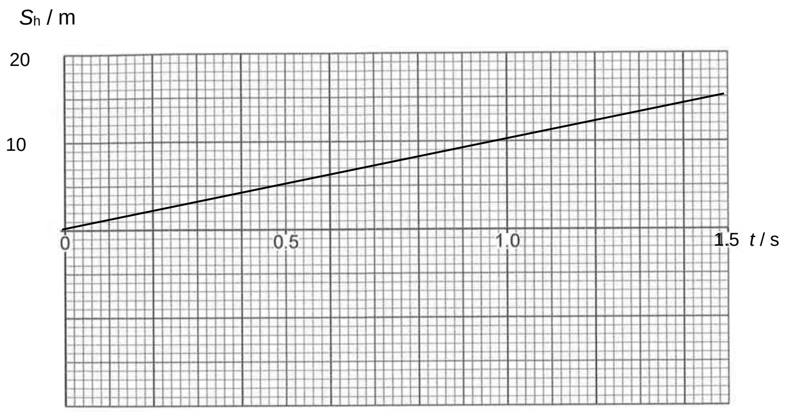
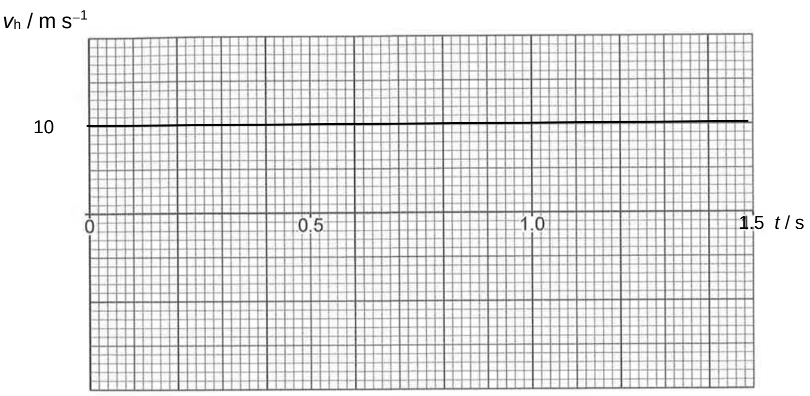
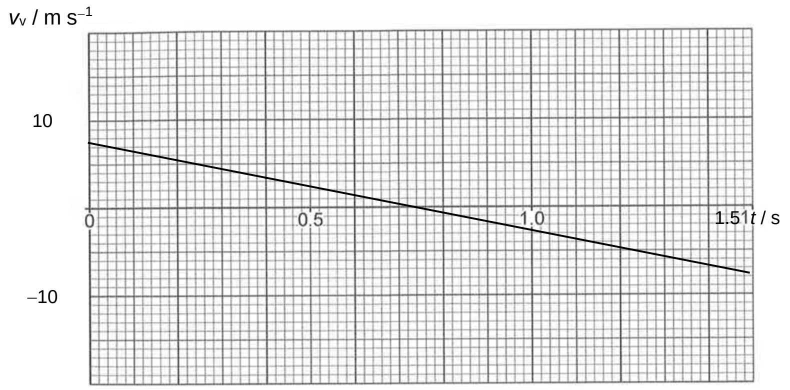
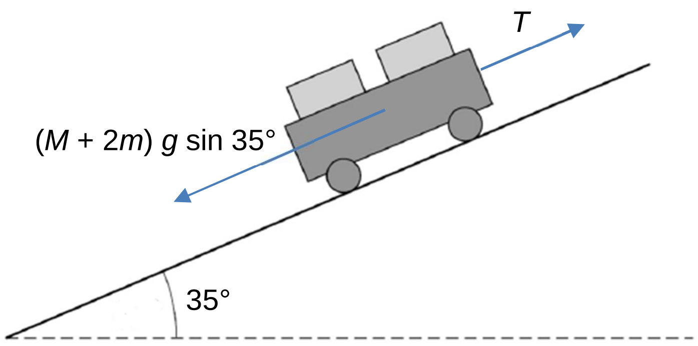
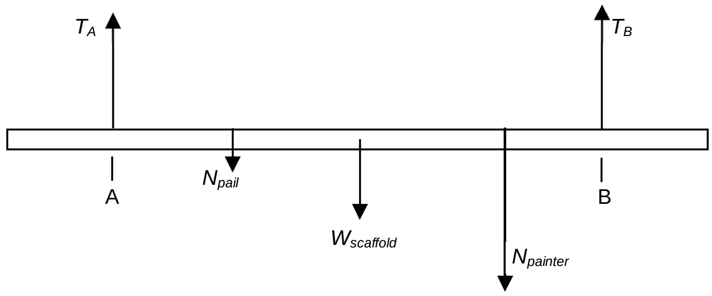
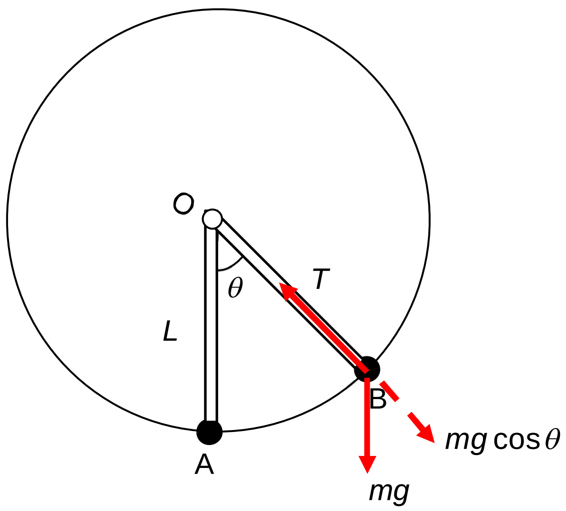
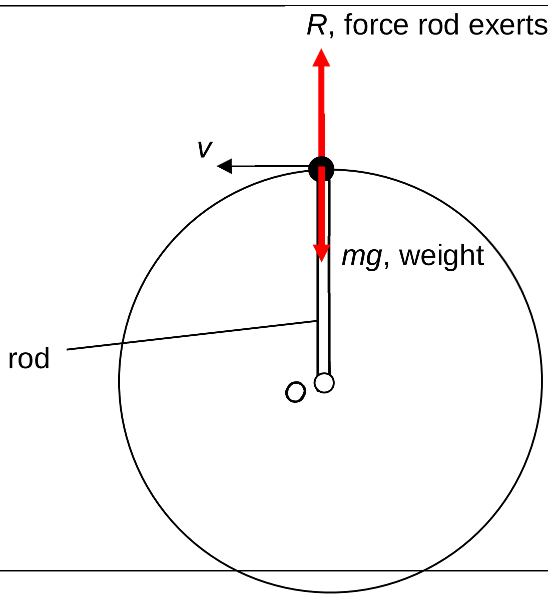
Answers to 2024 JC2 H1 Preliminary Examinations Paper 2

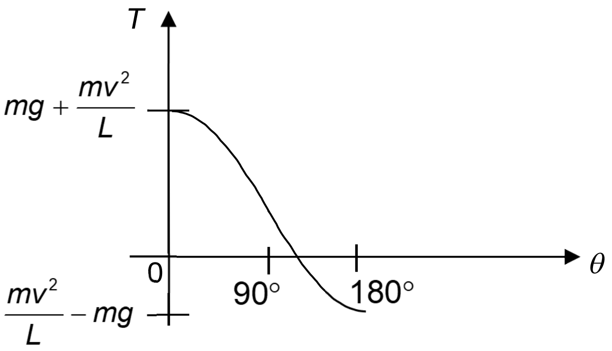
Suggested Solutions:

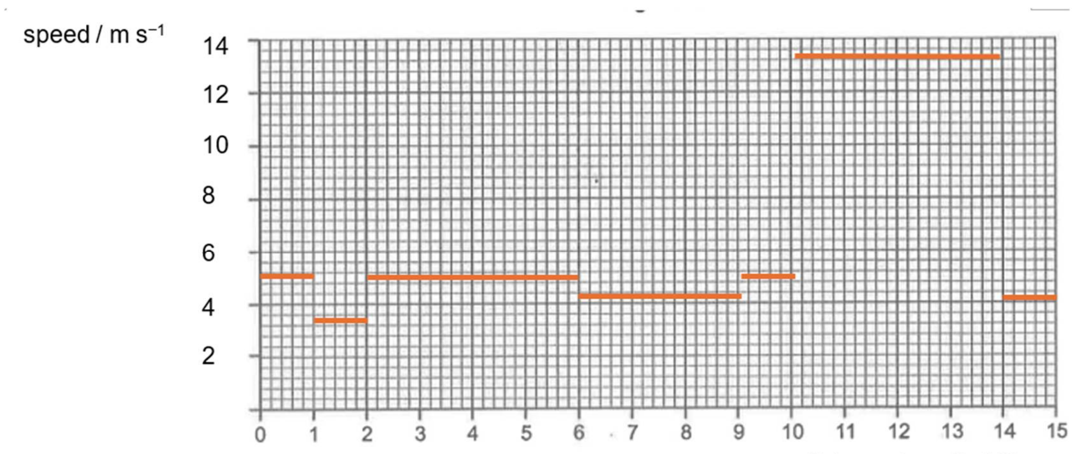
No.	Solution	Remarks
1(a)	$P = kAT^4$ $k = \dfrac{P}{AT^4}$ SI base units of k $= \dfrac{\text{W}}{\text{m}^2\ \text{K}^4} = \dfrac{\text{kg m}^2\ \text{s}^{-3}}{\text{m}^2\ \text{K}^4} = \text{kg s}^{-3}\ \text{K}^{-4}$	[1] for correct base units of power [1] for correct answer
1(b)	$P = v^3 b$ $v = \sqrt[3]{\dfrac{P}{b}} = \sqrt[3]{\dfrac{84 \times 10^3}{0.56}} = 53.133\ \text{m s}^{-1}$ $P = v^3 b$ $v = \sqrt[3]{\dfrac{P}{b}}$ $\dfrac{\Delta v}{v} = \dfrac{1}{3}\dfrac{\Delta P}{P} + \dfrac{1}{3}\dfrac{\Delta b}{b}$ $\dfrac{\Delta v}{53.133} = \dfrac{1}{3}(0.05) + \dfrac{1}{3}(0.07)$ $\Delta v = 2.1253\ \text{m s}^{-1}$ $\Delta v \approx 2\ \text{m s}^{-1}$	[1] for correct value of v [1] for correct substitution [1] for correct answer to 1 s.f.
2(a)	Using $s = ut + \frac{1}{2}at^2$ for vertical direction $0 = u(1.5) + \frac{1}{2}(-10)(1.5)^2$ $u = \frac{1}{2}(10)(1.5) = 7.5\ \text{m s}^{-1}$ OR Using $v = u + at$ for reaching maximum height, $0 = u + (-10)(\frac{1}{2} \times 1.5)$ $u = (10)(\frac{1}{2} \times 1.5) = 7.5\ \text{m s}^{-1}$	[1] substitution [1] answer
2(b)		[1] line starts at 0 m [1] ends at 15 m w.r.t. label at y-axis

2(b)		[1] horizontal line at 10 m s^{-1} w.r.t. label at y-axis
2(b)		[1] line starts at 7.5 m s^{-1} and cuts x-axis at 0.75 s [1] ends at –7.5 m s^{-1} w.r.t. label at y-axis
3(a)	The rate of change of momentum of a body(system) is proportional to the resultant force that acts on it and the momentum change takes place in the direction of the force.	[1]
3(b)	Impulse is defined as the product of force and time of impact.	[1]
3(c)(i)		[1] for drawing and labelling $(M+2m)g\sin 35°$ Or in words [1] for drawing and labelling T
3(c)(ii)	Trolley A: $(M+2m)g\sin 35° - T = (M+2m)a$ ------ (1) Trolley B: $T - Mg\sin 35° = Ma$ ------(2) (1)+(2): $(M+2m)g\sin 35° - Mg\sin 35° = (2M+2m)a$ $2mg\sin 35° = (2M+2m)a$	[1] for correct equation [1] for correct equation [1] for showing

	$a=\dfrac{mg\sin 35°}{M+m}$	$2mg\sin 35°$ $=(2M+2m)a$
3(c)(iii)	$a=\dfrac{25}{100}\left(\dfrac{30\times 9.81\times \sin 35°}{95+30}\right)=0.338\ \text{m s}^{-2}$ $9.0=\dfrac{1}{2}(0.338)t^2$ $t=7.3\ \text{s}$	[1] for correct acceleration [1] for correct substitution [1] for correct answer
3(c)(iv)	The flexible buffer stops the trolley over a prolonged period of time. Applying Newton's second law, this means that the rate of change of momentum of the trolley is reduced. The resultant force acting on the trolley is therefore reduced.	[1] [1]
4(a)		[2] all correct Or [1] any 3 correct (ignore length of arrows)
4(b)(i)	Taking moments about point A, sum of anti-clockwise moments = sum of clockwise moments $T_B\times 4.0=4.0\times 9.81\times 1.0+25.0\times 9.81\times 2.0+60.0\times 9.81\times 3.6$ $T_B=662\,\text{N}$	[1] sub [1] ans
4(b)(ii)	Sum of forces acting on scaffold = 0 N Upward forces = downward forces $T_A+T_B=4.0g+25.0g+60.0g$ $T_A=89\times 9.81-662$ $=211\text{N}$	[1] correct substitution [1] ans
4(c)	As the painter walks towards point A, the tension in rope A will increase and the tension in rope B will decrease. By considering the moment of the forces about point A, as x decreases, the sum of clockwise moment decreases. (Since the beam is in equilibrium), tension in rope B must decrease also. Hence the tension in rope A must increase, as total downward force is still the same.	[1] [1]
5(a)	Since the direction of motion of the body is always changing, its velocity is not constant and thus a resultant force acts on the body. Since the speed of the body is constant, the resultant force acts perpendicular to its velocity and thus, direction of motion, which is towards the centre of the circle.	[1] [1]

5(b)(i)	 The net force towards centre of the circle provides the centripetal force required to move in a circular path. $T - mg\cos\theta = \dfrac{mv^2}{r}$ $T = mg\cos\theta + \dfrac{mv^2}{L}$, as $r = L$.	[1] for statement and equation [1] for $r = L$
5(b)(ii)	The point where the force in the rod changes from tension to compression is when $T = 0$ N. $T = mg\cos\theta + \dfrac{mv^2}{L} = 0$ $mg\cos\theta = -\dfrac{mv^2}{L}$ $\cos\theta = -\dfrac{v^2}{gL} = -\dfrac{(2.0)^2}{(9.81)(0.80)} = -0.51$ $\theta = 120.6° = 120°$	[1] for $T = 0$ N [1] for correct substitution and answer
5(b)(iii)1.		[1] correct R and mg

5(b)(iii)2.	For circular motion, $mg - R = \frac{mv^2}{r}$ $R = mg - \frac{mv^2}{L}$ $= (0.050)(9.81) - \frac{(0.050)(2.0)^2}{(0.80)}$ $= 0.24\ \text{N}$	[1] for statement and equation [1] correct answer
5(b)(iv)		[1] graph is cosine and cuts at about 120° [1] correct max. and min. *T* values
5(b)(v)	The K.E. of the mass is constant but its G.P.E. is constantly changing. So as the mass is moving upwards, an external device is needed to supply energy to increase its G.P.E. As the mass moves downwards, its G.P.E. is decreasing and the external device must absorb the lost in G.P.E.	[1] energy supply [1] energy absorb
6(a)	$\text{average speed} = \frac{161 \times 10^3}{(4 \times 60 + 48)(60) + (20)}$ $= 9.3\ \text{m s}^{-1}$	[1] for substitution [1] for correct answer
6(b)	For 1st measurement, average speed $= \frac{1 \times 10^3}{200} = 5\ \text{m s}^{-1}$ For 2nd measurement, average speed $= \frac{1 \times 10^3}{300} = 3.3\ \text{m s}^{-1}$ For 3rd measurement, average speed $= \frac{4 \times 10^3}{800} = 5\ \text{m s}^{-1}$ For 4th measurement, average speed $= \frac{3 \times 10^3}{700} = 4.3\ \text{m s}^{-1}$ For 5th measurement, average speed $= \frac{1 \times 10^3}{200} = 5\ \text{m s}^{-1}$ For 6th measurement, average speed $= \frac{4 \times 10^3}{300} = 13.3\ \text{m s}^{-1}$ For 7th measurement, average speed $= \frac{1 \times 10^3}{250} = 4\ \text{m s}^{-1}$	

	 Fig. 6.1c [1] for correct low average speed for 1 km to 2 km, 6 to 9 km, 14 to 15 km [1] for correct medium average speed for 0 to 1 km, 2 to 6 km, 9 to 10 km [1] for correct high average speed for 10 km to 14 km [1] all speed – distance graphs are horizontal	
6(c)(i)	work done $= Fd = (24)(3000)$ $= 72\ 000$ J	[1]
6(c)(ii)	power per unit mass $= \dfrac{72 \times 10^3}{(700)(78)}$. $= 1.3$ W kg^{-1}	[1] correct substitution [1] correct time of 700 s [1] correct answer
6(c)(iii)	From the 6th km to the 9th km mark, the K.E. is constant. As the height increased, as such, energy is needed as there is an increase in G.P.E. power per unit mass to increase G.P.E. $= \dfrac{mgh}{mt}$ $= \dfrac{(9.81)(400)}{(700)}$ $= 5.6$ W kg^{-1} total power per unit mass $= 1.3$ W kg^{-1} $+ 5.6$ W kg^{-1} $= 6.9$ W kg^{-1}	[1] correct gain in height [1] correct 5.6 W kg^{-1} [1] correct answer
6(d)(i)	power per unit mass $= \dfrac{12000 \times 10^3}{(70)(24 \times 60 \times 60)}$ $= 1.98$ W kg^{-1}	[1] for correct answer

6(d)(ii)	The cyclist needs higher power per unit mass as the cyclist has to provide energy as work against resistive force, as well as to move up hills while cycling, increasing the cyclist's G.P.E.	[1] any correct Physics relevant to difference
7(a)(i)	At V = 12 V, I = 2.5 A $\Rightarrow \frac{I}{V} = 0.208$ At V = 6 V, I = 1.25 A $\Rightarrow \frac{I}{V} = 0.208$ At V = 9.6 V, I = 2.0 A $\Rightarrow \frac{I}{V} = 0.208$ Since ratio of I to V is constant, I is proportional to V.	[1] show at least 2 values of ratio of $\frac{I}{V}$ or $\frac{V}{I}$. [1] conclusion
7(a)(ii)1.	Resistance of resistor X = $\frac{12}{2.5}$ = 4.8 Ω	[1] answer
7(a)(ii)2.	Current in wire AB = $\frac{9.0}{4.0+5.0}$ = 1.0 A	[1] answer
7(a)(ii)3.	Current in resistor X = $\frac{9.0}{4.8+2.7}$ = 1.2 A	[1] answer
7(a)(ii)4.	Resistance of wire AC = $\frac{0.70}{1.0} \times 4.0 = 2.8$ Ω Potential difference across AC = $\frac{2.8}{4.0+5.0} \times 9.0 = 2.8$ V Potential difference across AD = $\frac{4.8}{4.8+2.7} \times 9.0 = 5.76$ V Potential difference between C and D = 5.76 – 2.8 = 2.96 V = 3.0 V	[1] value of V_{AC} [1] value of V_{AD} [1] answer
7(a)(ii)5.	With internal resistance, the <u>potential difference across the power supply would be less</u> than 9.0 V. The potential difference across AC and AD would also be less, and hence the <u>answer in **(ii)4** would be less</u>.	[1]
7(b)(i)	Electric field strength E = $\frac{V}{d} = \frac{40-(-40)}{40\times10^{-3}}$ = 2.0 × 10^3 V m^{-1}	[1] answer
7(b)(ii)	Acceleration a = $\frac{F}{m} = \frac{eE}{m} = \frac{(1.6\times10^{-19})(2.0\times10^{3})}{9.11\times10^{-31}}$ = 3.51 × 10^{14} m s^{-2}	[1] substitution [1] answer (2 or 3 s.f.)

7(b)(iii)	Duration of time for electron to stay in electric field is given by $t = \frac{s}{v} = \frac{80\times10^{-3}}{1.5\times10^{7}}$ = 5.333 × 10^{-9} s Vertically, using $v = u + at$, $v = 0 + (3.51 \times 10^{14})(5.333 \times 10^{-9})$ $= 1.87 \times 10^{6}$ m s^{-1} $= 1.9 \times 10^{6}$ m s^{-1}	[1] for value of t [1] for velocity 1.87×10^{6} m s^{-1}
7(b)(iv)	$\tan\theta = \frac{v_y}{v_x} = \frac{1.9\times10^{6}}{1.5\times10^{7}} \rightarrow \theta = 7.2°$	[1] answer
7(b)(v)1.	Magnetic force provides centripetal force needed for circular motion, $Bev = \frac{mv^2}{R}$ $\rightarrow R = \frac{mv}{Be} = \frac{(9.11\times10^{-31})(1.9\times10^{6})}{(1.62\times10^{-4})(1.60\times10^{-19})}$ $= 6.68 \times 10^{-2}$ m = 6.7×10^{-2} m	[1] statement [1] substitution [1] answer
7(b)(v)2.	$Bev = \frac{mv^2}{R} \rightarrow Be = \frac{mv}{R} = m\omega = \frac{2\pi m}{T}$ $\rightarrow T = \frac{2\pi m}{Be} = \frac{2\pi(9.11\times10^{-31})}{(1.62\times10^{-4})(1.60\times10^{-19})}$ = 2.21 × 10^{-7} s = 2.2 × 10^{-7} s	[1] substitution [1] answer
8(a)(i)	Change in mass $=(209.98313 - 205.97470 - 4.00263)$u $= 5.8\times10^{-3}$u $= 9.628\times10^{-30}$ kg Energy released $=(9.628\times10^{-30})(3.00\times10^{8})^2$ $= 8.6652\times10^{-13}$ J $= 5.41575$ MeV ≈ 5.42 MeV	[1] for correct change in mass [1] for correct substitution [1] for correct answer
8(a)(ii)	Kinetic energy of α-particle $\frac{1}{2}(4.00263)(1.66\times10^{-27})(v_\alpha)^2 = (0.98)(8.6652\times10^{-13})$ $v_\alpha = 1.599\times10^{7}$ m s^{-1} $\approx 1.6\times10^{7}$ m s^{-1}	[1] for correct substitution [1] for correct answer
8(a)(iii)	The <u>total momentum must be conserved during</u> the decay. OR The lead nucleus must <u>recoil</u> after the decay. OR	[1]

	The lead nucleus moves in <u>the opposite direction</u> to the α-particle. Therefore the lead nucleus will also have kinetic energy.	[1]
8(b)(i)	${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{142}_{54}\text{Xe} + {}^{90}_{38}\text{Sr} + 4\,{}^{1}_{0}\text{n}$ 4 neutrons are produced.	[1]
8(b)(ii)	The binding energy of a nucleus is the minimum amount of energy required to break the nucleus into its constituent particles. OR The binding energy of a nucleus is the energy released when a nucleus is formed from its constituent particles.	[1]
8(b)(iii)	Energy released $=142(8.37)+90(8.72)-235(7.59)$ $=189.69\text{ MeV}$ $\approx 190\text{ MeV}$	[1] for correct substitution [1] for correct answer
8(b)(iv)	It has low B.E. per nucleon.	[1]
8(b)(v)1.	The half-life of a radioactive nuclide is the time taken for a sample's activity to reduce to half its initial value.	[1]
8(b)(v)2.	$\dfrac{\text{number of decayed nuclei of xenon-142}}{\text{number of undecayed nuclei of xenon-142}}=31$ $\dfrac{N_0-N}{N}=31$ $N_0=32N$ $\dfrac{N}{N_0}=\dfrac{1}{32}$ $N=N_0 e^{-\frac{\ln 2}{t_{\frac{1}{2}}}t}$ $\dfrac{1}{32}=e^{-\frac{\ln 2}{t_{\frac{1}{2}}}(6.0)}$ $t_{\frac{1}{2}}=1.2\text{ s}$ OR $N=\dfrac{1}{32}N_0=\left(\dfrac{1}{2}\right)^n N_0$	[1] for $\dfrac{N}{N_0}=\dfrac{1}{32}$ [1] for correct substitution [1] for correct answer

	$\frac{1}{32} = \left(\frac{1}{2}\right)^n$ $n = 5$ $5t_{\frac{1}{2}} = 6.0\ \text{s}$ $t_{\frac{1}{2}} = 1.2\ \text{s}$	
8(c)	Counts is reduced significantly / by almost half by the sheet of paper, therefore alpha particles are present. Counts is reduced significantly / almost all of the remaining radiation is stopped by the aluminium, therefore beta particles are present. Counts with lead is larger than with aluminium (or almost the same), therefore no gamma is present. The counts with aluminium and lead are essentially the same. This is because of background radiation / the background radiation is approximately 25 counts per minute. Randomness of radioactive decay is the reason for the increased value with lead.	[1] [1] [1] [1] [1] Any 4 correct answers