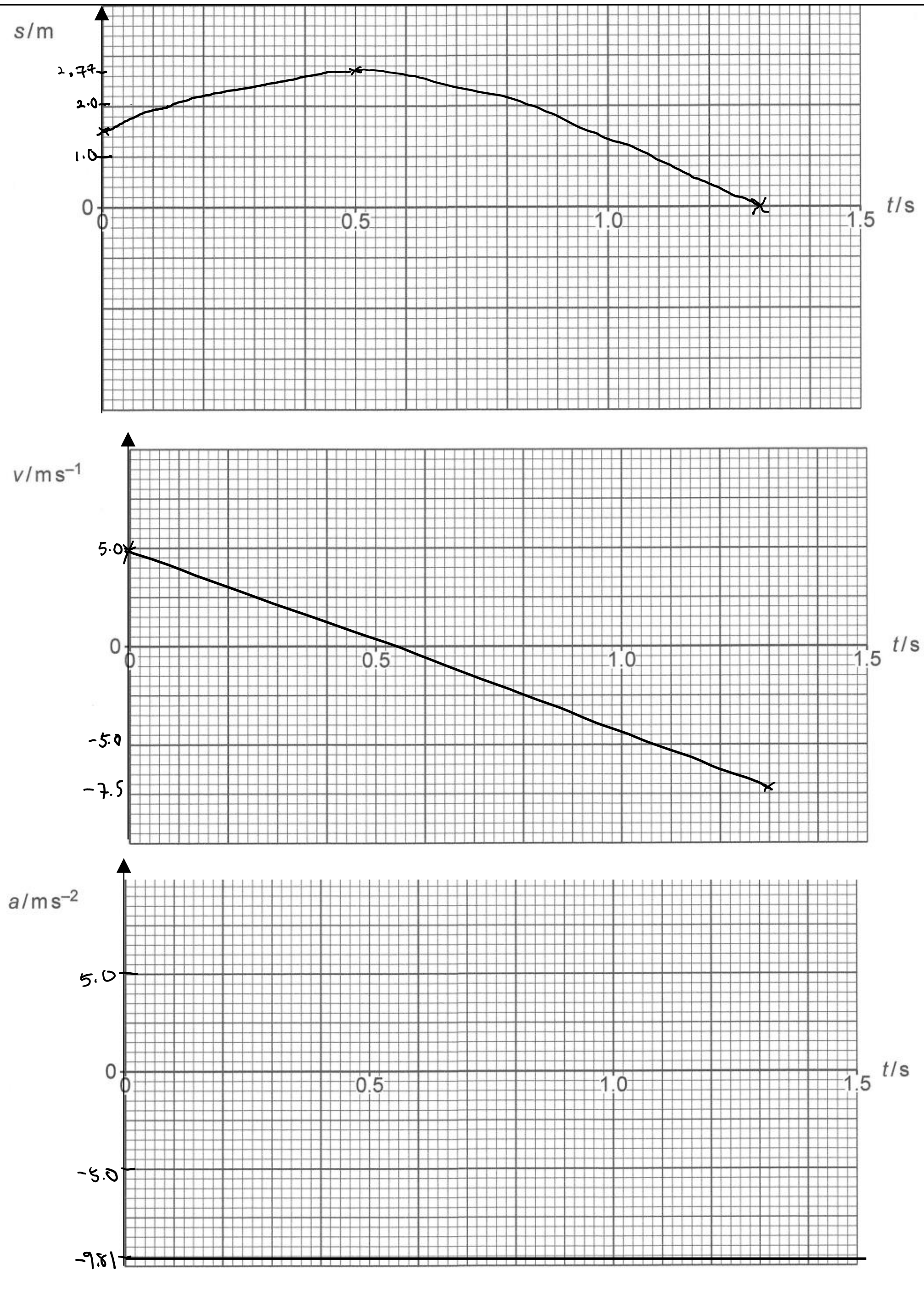
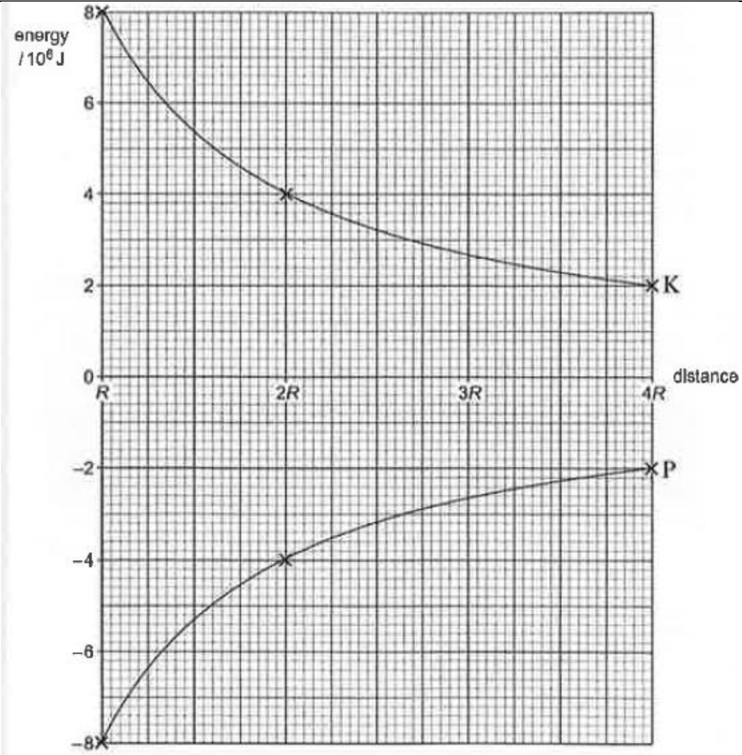
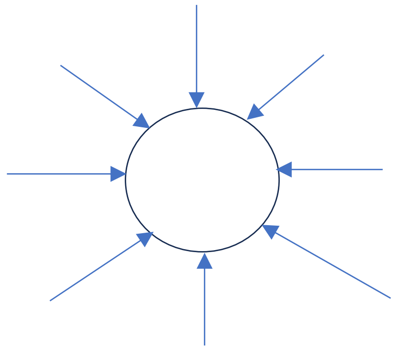
2023 A Levels H2 Physics 9749/02 Paper 3 suggested solutions

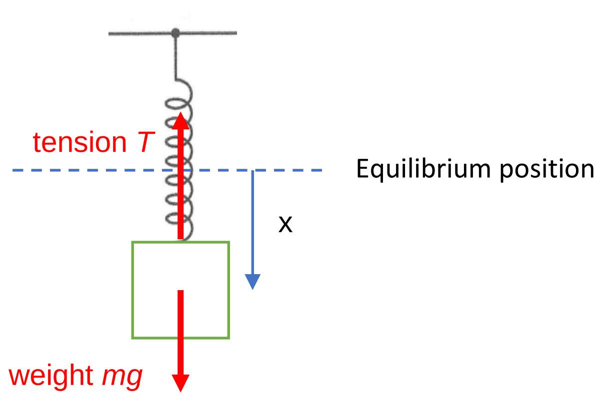
1a	$x = \dfrac{L^3 gM}{4wt^3 E}$ units of $x = \text{m}$ units of $\text{E} = \left[\dfrac{Force}{area}\right] = \dfrac{\text{kg m s}^{-2}}{\text{m}^2}$ units of $\dfrac{L^3 gM}{4wt^3 E} = \dfrac{\text{m}^3 \times \text{m s}^{-2} \times \text{kg}}{\text{m} \times \text{m}^3 \times \dfrac{\text{kg m s}^{-2}}{\text{m}^2}}$ $= \dfrac{\text{m}^4 \times \text{s}^{-2} \times \text{kg}}{\text{m}^4 \times \text{kg m}^{-1}\ \text{s}^{-2}} = \text{m}$ Since the unit of x is the same as unit of $\dfrac{L^3 gM}{4wt^3 E}$, the equation is homogenous.
1b	$E = \dfrac{L^3 gM}{4wt^3 x}$ $= \dfrac{0.800 \times 9.81 \times \dfrac{300}{1000}}{4 \times \dfrac{2.10}{100} \times \left(\dfrac{4.56}{1000}\right)^3 \times \dfrac{1.00}{100}}$ $= 1.8918 \times 10^{10}\ \text{Pa}$ $\dfrac{\Delta E}{E} = 3\dfrac{\Delta L}{L} + \dfrac{\Delta M}{M} + \dfrac{\Delta w}{w} + 3\dfrac{\Delta t}{t} + \dfrac{\Delta x}{x}$ $= 3\left(\dfrac{0.005}{0.800}\right) + \dfrac{2}{300} + \dfrac{0.02}{2.10} + 3\left(\dfrac{0.01}{4.56}\right) + \dfrac{0.01}{1.00}$ $= 0.0515$ % uncertainty $= 0.0515 \times 100\% = 5.2\%$ $E = 1.89 \times 10^{10}\ \text{Pa} \pm 5.2\%$ *Note: Value of E should be 3 s.f. since all the variables are 3 s.f. in the question.
2ai	$v^2 = u^2 + 2as$ $v^2 = (5.0)^2 + 2(-9.81)(-1.5)$ $v = 7.4\ \text{m s}^{-1}$

2aii	$v = u + at$ $-7.4 = 5.0 - 9.81t$ $t = 1.3$ s
2bi	
3a	Electric current is the rate of flow of charge.
3b	number of charge carriers N in the rod = number density n × volume = *nAl* charge in the rod Q = *Nq* = *nAlq* current $I = \frac{Q}{t} = \frac{nAlq}{t}$ = nAvq since v = $\frac{l}{t}$
3ci	$v = \frac{I}{nAq}$ $n = \frac{N}{Al} \Rightarrow nA = \frac{N}{l}$ subst this in first equation gives $v = \frac{Il}{Nq} = \frac{2.00 \times 3.00}{1.45 \times 10^{23} \times 1.60 \times 10^{-19}}$ = 2.59 × 10^{-4} m s^{-1}

3cii	electrons in tungsten wire move in random directions at high speed (due to temperature) while the drift velocity of the electrons is the average velocity in the direction of the net flow of the electrons along the wire (which is typically very slow) so the drift velocity will be less, in fact, much less than the mean speed of the electrons
4a	The magnetic flux density of a magnetic field is the force per unit length, per unit current, on a long straight conductor placed at right angles to the magnetic field.
4b	Since the reading on the balance decreases, there is a magnetic force on by the wire on the magnet, upwards. Hence, by Newton's third law, there is a magnetic force of equal magnitude by the magnet on the wire, downwards. Since the force on the wire is downwards, and the magnetic field is from north to south pole, by Fleming's Left Hand Rule the current in the wire is from X to Y.
4ci	Average reading of the mass is when the current is off = $\frac{202.17+201.62}{2}=201.895$ g Thus the change in the reading due to the force by the wire = $202.17-201.895=0.275$ g The magnetic force of the wire on the magnet = $0.295\times10^{-3}\times9.81=2.70\times10^{-3}$ N The magnetic flux density: $B=\frac{F}{I\times L}=\frac{2.70\times10^{-3}}{1.6\times0.12}=0.0141\text{ T}$
4cii	Since the force on the magnet is given by $F=BIL$ it is independent of the resistivity of the material. As long as the current remains the same, the force on the magnet is the same and the reading is the same as in (b)(ii).
5a	The gravitational potential at a point is the work done per unit mass by an external force in bringing a small test mass from infinity to that point without a change in kinetic energy.
5b	By conservation of energy, the initial total energy of the projectile at surface of planet = final total energy of the projectile at infinity (where it no longer experiences the gravitational field of the planet and hence will not return) Since the projectile is launched with v (minimum speed), the kinetic energy of the mass at infinity is zero, E_K = 0 (which means that *it stops once it reaches infinity*). Since the gravitational potential energy at infinity = 0, the total energy of the mass at infinity = $E_{Pf}+E_{Kf}=0+0$ Assuming no resistive forces act on mass *m*, Total energy of the mass at surface of planet = Total energy of the mass at infinity $-\frac{GMm}{r}+\frac{1}{2}mv^2=0$ where m is the mass of the projectile. $v=\sqrt{\frac{2GM}{r}}$ Note: total energy is zero at all times for the projectile.

5ci and 5cii	 Important to draw the curves properly (can bring curved ruler to theory paper) Important to label the graphs K and P
6ai	Since the mean kinetic energy of a gas molecule is proportional to the gas' thermodynamic temperature, the values of the mean kinetic energy of the gas molecule in both containers are the same as the gases are at the same temperature. Therefore, the ratio is 1.0.
6aii	$pV = NkT \Rightarrow N = \frac{pV}{kT}$ Substituting and given that *p*, *k* and *T* are constants, $\frac{N_A}{N_B} = \frac{V_A}{V_B} = \frac{V}{4V}$ Therefore, ratio is 0.25.
6aiii	$\frac{1}{2}m < c^2 > = \frac{3}{2}kT \Rightarrow c_{rms} = \sqrt{< c^2 >} = \sqrt{\frac{3kT}{m}}$ Substituting and given that *k* and *T* are constants, $\frac{C_{rmsA}}{C_{rmsB}} = \frac{\sqrt{m_B}}{\sqrt{m_A}} = \frac{\sqrt{2m}}{\sqrt{m}}$ Therefore, ratio is 1.4 (2 s.f.).

6b	From (a)(iii), $C_{rms\ A}$ = 1.4142 $C_{rms\ B}$ = 1329.36 m s^{-1} $\frac{1}{2}M_R < c^2 > = \frac{3}{2}kT$ $\frac{1}{2}(0.0040)(1329.36)^2 = \frac{3}{2}(8.31)T$ T = 280 K (2 s.f.) Note: $\frac{1}{2}m < c^2 > = \frac{3}{2}kT$ is for one molecule. Be aware of how molar mass, number of molecules, total mass of the gas in container and mass of one molecule are related to one another.
7a	The electric field strength at a point is the electric force per unit positive charge acting on a small stationary charge placed at that point.
7bi	 8 field lines to be drawn, with correct direction (pointing towards the sphere). The spacing between the lines must be equally spaced around the sphere and must be perpendicular to surface.
7bii	$E = -\frac{dV}{dr}$ The electric field strength at a point is numerically equal to the potential gradient at that point hence E = 130 V m^{-1}. $130 = \frac{Q}{4\pi\varepsilon_o r^2}$ $130 = \frac{Q}{4\pi(8.85\times10^{-12})\left(\frac{15+40}{100}\right)^2}$ $Q = 4.4\times10^{-9}C$
8ai	$k = \frac{F}{x} = \frac{4.0}{0.20} = 20 \text{ N m}^{-1}$
8aii	energy stored $= \frac{1}{2}Fx = \frac{1}{2}\times3.0\times0.15 = 0.225$ or 0.23 J Note: the extension is 0.15 m and not 0.20 m
8aiii	total GPE transferred = mgh = 3.0 × 0.15 = 0.45 J
8b	The difference is due to work done by external forces in reducing the kinetic energy of the object so that the object come to a rest in a stationary equilibrium. or The difference is due to work done in lowering the object without a change in kinetic energy.

8c	Consider the object at distance x below the equilibrium and take down as positive:  (Let a = accleration in the direction of x) Applying Newton's 2nd law to the object: $\downarrow$ $mg - T = ma$ $mg - k(0.15 + x) = ma$ but $mg = k(0.15)$ (at the equilibrium position), so $0 - kx = ma$ $\Rightarrow a = -\frac{k}{m}x$ Note: a is opposite to displacement x
8di	$\omega^2 = \frac{k}{m} = \frac{20}{3.0 / 9.81} \Rightarrow \omega = \sqrt{65}$ taking up as positive: $x = x_0 \sin\omega t = 3.2\sin(\sqrt{65} \times 0.50) = -2.5$ cm magnitude of displacement = 2.5 cm Note: use radian mode when using the sin function
8dii	taking up as positive: $v = \omega x_0 \cos\omega t = \sqrt{65} \times 3.2\cos(\sqrt{65} \times 0.50) = -16$ cm s^{-1} magnitude of velocity = 16 cm s^{-1} Note: use radian mode when using the cos function

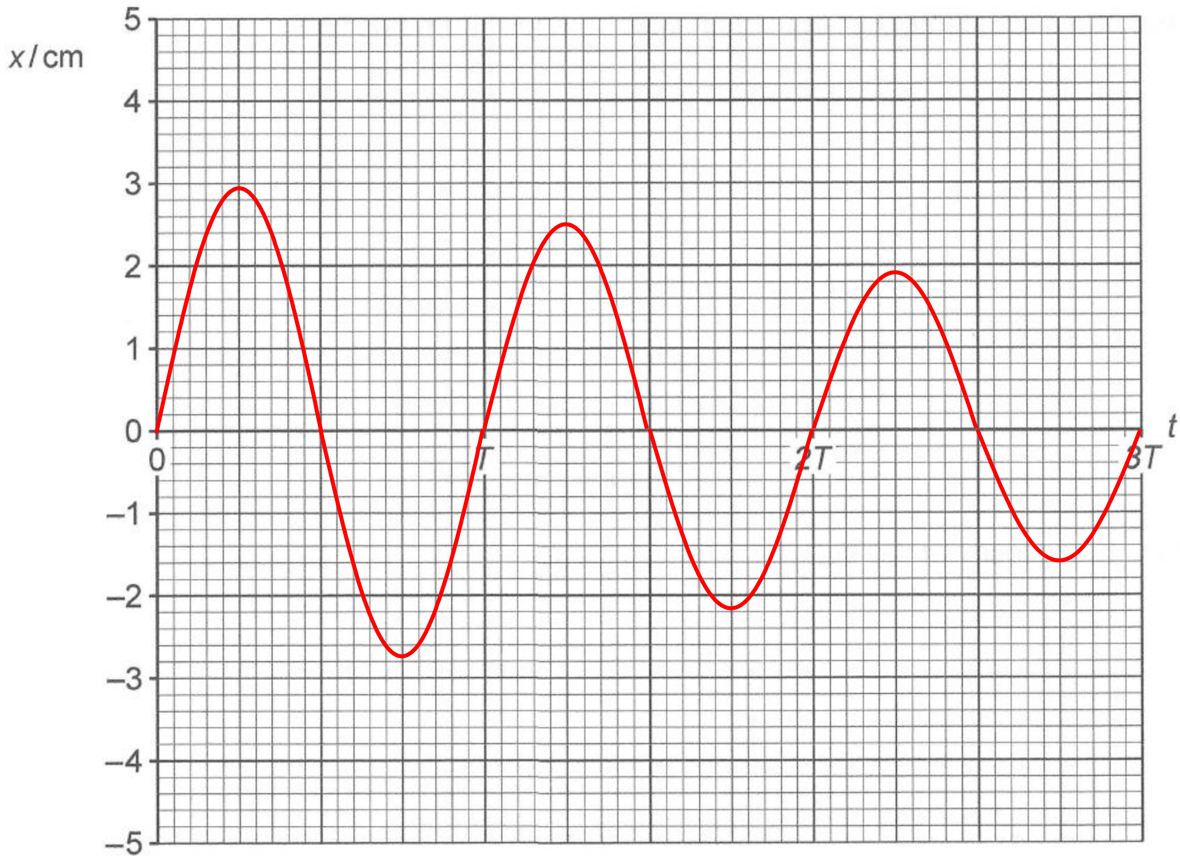
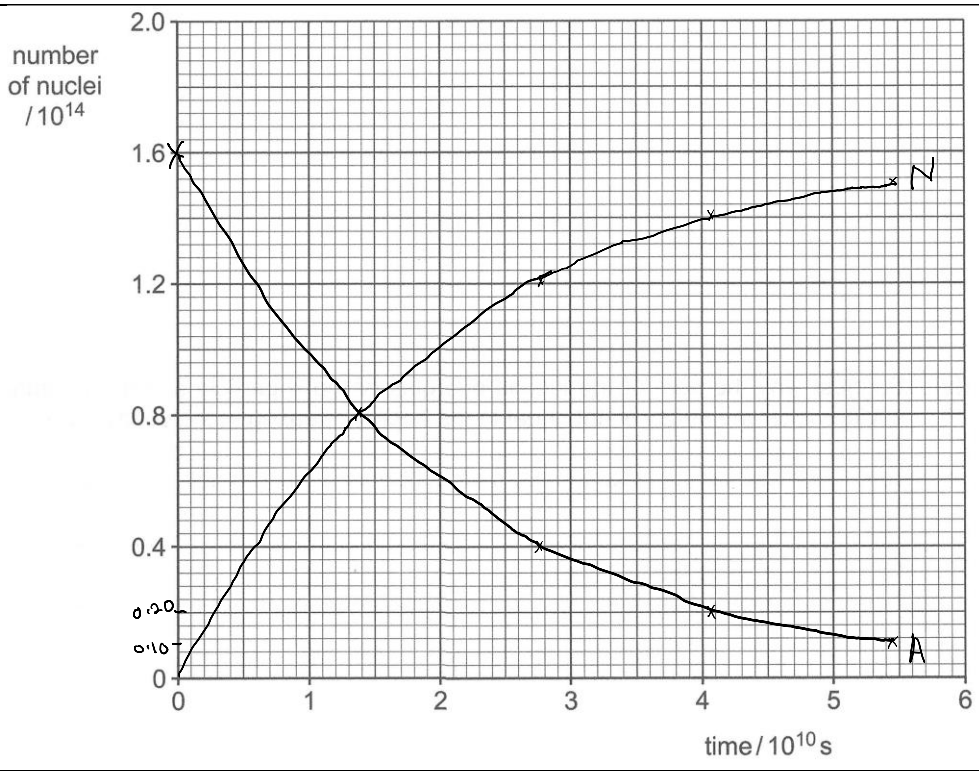
<table>
<tr><td>8e</td><td>


Fig. 8.4

note:

amplitude of the first peak will be lesser than 3.2 cm
amplitude of subsequent peaks decreases (exponentially with time)
period remains the same

</td></tr>
<tr><td>8fi</td><td>The tension is the same, so extension of each spring is the same, so the total extension of the combination is twice the extension of the single original spring.</td></tr>
<tr><td>8fii</td><td>The effective force constant of the combination is half since the total extension is twice for the same tension.
$\omega = \sqrt{\frac{k}{m}}$, so the angular frequency ω of the oscillations will be $\frac{1}{\sqrt{2}}$ times the original angular frequency, so the new period will be $\sqrt{2}$ or 1.4 times the original period</td></tr>
<tr><td>9a(i)</td><td>Mass defect = mass of reactants – mass of products
$= m_{Am} - m_{Np} - m_{He} = (400.19774 - 393.54304 - 6.64466) \times 10^{-27}$
$= 0.01004 \times 10^{-27}$ kg
Energy released $= 0.01004 \times 10^{-27} \times (3.0 \times 10^{8})^{2}$
$= 9.0 \times 10^{13}$ J</td></tr>
<tr><td>9a(ii)</td><td>Principle of Conservation of Momentum states that the total momentum of a system of bodies remain constant provided no external resultant force acts on the system.</td></tr>
</table>

9a(iii)	K.E. of He $= \frac{1}{2} m_{He} \left(v_{He}\right)^2$ $v_{He} = \sqrt{\frac{2 \times \text{K.E. of He}}{m_{He}}} = \sqrt{\frac{2 \times 8.784 \times 10^{-13}}{6.64466 \times 10^{-27}}}$ $= 1.626 \times 10^{7}\ \text{m s}^{-1}$ By Principle of Conservation of Momentum, momentum of Am-241 = momentum of He + momentum of Np $0 = m_{He} v_{He} - m_{Np} v_{Np}$ (taking direction of momentum of He to be positive) $v_{Np} = \frac{\left(6.64466 \times 10^{-27}\right)\left(1.626 \times 10^{7}\right)}{393.54304 \times 10^{-27}} = 2.745 \times 10^{5}\ \text{m s}^{-1}$ K.E. of Np $\frac{1}{2} m_{Np} \left(v_{Np}\right)^2 = \frac{1}{2}\left(393.54304 \times 10^{-27}\right)\left(2.745 \times 10^{5}\right)^2$ $= 1.483 \times 10^{-14}\ \text{J}$
9a(iv)	There could have been gamma radiation produced during the decay. (This is alpha decay, not beta decay. Hence there is no production of neutrino).
9b(i)	$A = \lambda N$ $N = \frac{A}{\lambda} = \frac{8130}{5.08 \times 10^{-11}} = 1.6 \times 10^{14}$ nuclei
9b(ii)	$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{5.08 \times 10^{-11}} = 1.36 \times 10^{10}\ \text{s}$
9b(iii)(iv)	
c(i)	Initial activity of the beta emitter is much higher than the americium-241 as the decay constant is greater. Since $A = \lambda N$, with the same number of initial particles, the beta emitter will have a higher activity.
c(ii)	Time taken for the beta emitter to fall to 1 Bq will be shorter than americium-241 as it has a much shorter half-life than americium-241.