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EUNOIA JUNIOR COLLEGE
JC2 MID-YEAR EXAMINATIONS 2022
9749 PHYSICS
MARK SCHEME

Paper 3
Longer Structured Questions

Qns	Answer	Marks
1(a)(i)	gravitational force of attraction per unit mass acting on (OR experienced by) a small test mass placed at that point (in the gravitational field)	**1**
1(a)(ii)	gravitational force of attraction between **two point masses** is directly proportional to the product of the masses and inversely proportional to the **square of separation between the masses**	**1**
	Let m be the mass of an object distance R away from Mass M	**1**
	field strength is gravitational force of attraction per unit mass experienced by **small test mass** placed at that point $\frac{F}{m}=\frac{1}{\cancel{m}}\frac{GM\cancel{m}}{r^2}=\frac{GM}{r^2}$	**1**
1(b)(i)	volume of star $=\frac{4}{3}\pi r^3$ $=\frac{4}{3}\pi\left(2.7\times10^4\right)^3$ $=8.245\times10^{13}\ \text{m}^3$	**1**
	$\rho=\frac{m}{V}=\frac{6.2\times10^{30}}{\frac{4}{3}\pi\left(2.7\times10^4\right)^3}=7.52\times10^{16}\ \text{kg m}^{-3}$	**1**
1(b)(ii)	(words to effect of) density increase closer to centre	**1**
	(words to effect of) outer layers compress inner layers	**1**

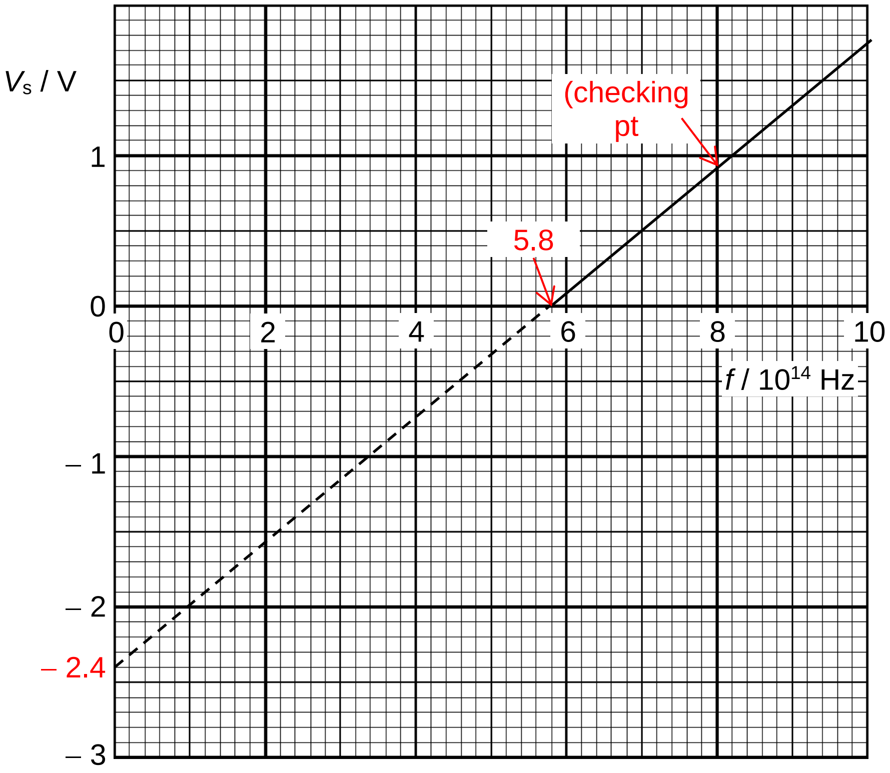
Qns	Answer	Marks
1(b)(iil)	By conservation of energy: loss in KE $=$ gain in GPE $\frac{1}{2}mv^2 - 0 = 0 - \left(-\frac{GMm}{r}\right)$ $v = \sqrt{\frac{2Gm}{r}} = \sqrt{\frac{2\left(6.67\times10^{-11}\right)\left(6.2\times10^{30}\right)}{2.7\times10^{4}}}$ $= 1.75\times10^{8}\ \text{m s}^{-1}$	1 1

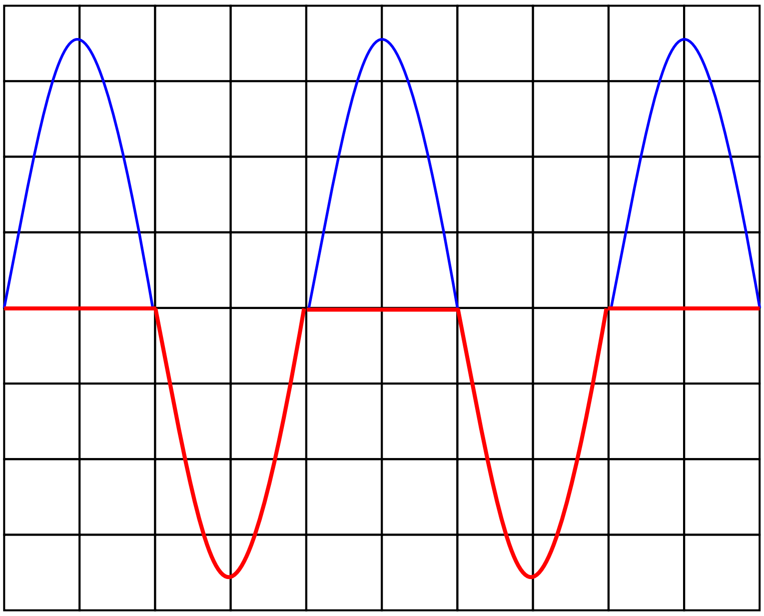
Qns	Answer	Marks
2(a)	oscillatory motion where acceleration is directly proportional to displacement from equilibrium position and directed opposite to displacement	**1**
2(b)(i)	amplitude $x_0 = 0.7$ m $\lvert v \rvert = \omega\sqrt{x_0^2 - x^2} = \left(\frac{2\pi}{T}\right)\sqrt{x_0^2 - x^2}$ $= \left(\frac{2\pi}{4.0}\right)\sqrt{0.7^2 - 0.2^2}$ $= 1.05 \text{ m s}^{-1}$	**1** **1**
2(b)(ii)	relative to equilibrium: $x = -0.15$ m OR relative to ground: $x = 0.55$ m $x = x_0 \sin \omega t$ $= x_0 \sin\left[\left(\frac{2\pi}{T}\right)t\right]$ $x = x_0 \sin \omega t + 0.7$ $0.55 = x_0 \sin\left[\left(\frac{2\pi}{T}\right)t\right] + 0.7$ $-0.15 = (0.7) \sin\left[\left(\frac{2\pi}{4.0}\right)t\right]$ $\text{duration} = 2.13748 - (-0.13748)$ $= 2.27$ s (can be by GC)	**1** **1**

Qns	Answer	Marks
3(a)(i)	$E = mL_v + h_{\text{loss}} = Pt$ $P = \left(\frac{m}{t}\right)L_v + \frac{h_{\text{loss}}}{t}$ $\left.\begin{aligned} P_1 &= \left(\frac{m}{t}\right)_1 L_v + \left(\frac{h_{\text{loss}}}{t}\right)_1 \quad \_\_\_\_(1) \\ P_2 &= \left(\frac{m}{t}\right)_2 L_v + \left(\frac{h_{\text{loss}}}{t}\right)_2 \quad \_\_\_\_(2) \end{aligned}\right\}$ $(1)-(2)$ $P_1 - P_2 = \left[\left(\frac{m}{t}\right)_1 - \left(\frac{m}{t}\right)_2\right]L_v$ $L_v = \frac{P_1 - P_2}{\left(\frac{m}{t}\right)_1 - \left(\frac{m}{t}\right)_2} = \frac{I_1V_1 - I_2V_2}{\left(\frac{m}{t}\right)_1 - \left(\frac{m}{t}\right)_2}$ $= \frac{(5.0)(78)-(4.0)(60)}{\frac{16\times10^{-3}}{1.5\times60} - \frac{10\times10^{-3}}{1.5\times60}}$ $= 2.25\times10^{6}\ \text{J kg}^{-1}$	**1** **1** **A0**
3(a)(ii)	pure substances undergo phase change at constant temperature (words to that effect) so temperature difference with surrounding kept constant	**1**
3(b)(i)	$Q = mL$ $= (1.0)(2.25\times10^{6})$ $= 2.25\times10^{6}\ \text{J}$	**1** **1**
3(b)(ii)	$W_{\text{on}} = -p\Delta V = -p(V_{\text{final}} - V_{\text{initial}})$ $= -(1.0\times10^{5})(1.67 - 1.04\times10^{-3})$ $= -(1.0\times10^{5})(1.66896)$ $W_{\text{by}} = +1.67\times10^{5}\ \text{J}$	**1** **1**
3(b)(iii)	$\Delta U = Q + W$ $= 2.25\times10^{6} + (-1.67\times10^{5})$ $= 2.08\times10^{6}\ \text{J}$	**1**
3(b)(iv)	$\Delta\text{PE} = \text{PE}_{\text{gas}} - \text{PE}_{\text{liquid}}$ $\text{PE}_{\text{gas}} = \Delta\text{PE} + \text{PE}_{\text{liquid}}$ $= 2.08\times10^{6} - 3.41\times10^{5}$ $= 2.42\times10^{6}\ \text{J}$	**1** **1**

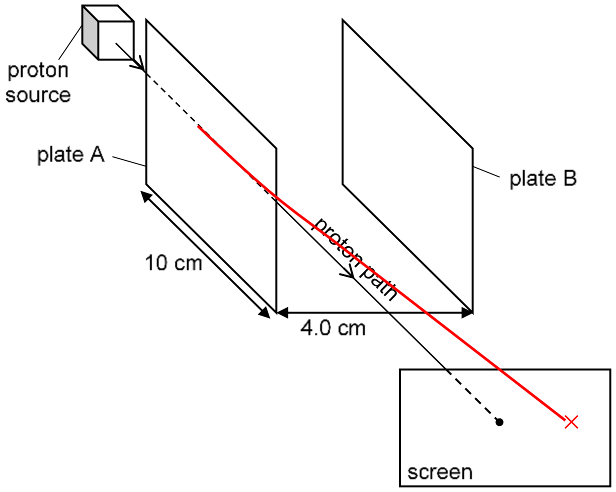
Qns	Answer	Marks
3(b)(v)	pure substances undergo phase change at constant temperature so total translational kinetic energy of particles remain constant	**B0**
	large increase in volume for phase change from liquid to gas so separation between molecules instead	**1**
	intermolecular bonds are complete broken as potential energy between particles increases	**1**
	work is done against atmosphere	**1**

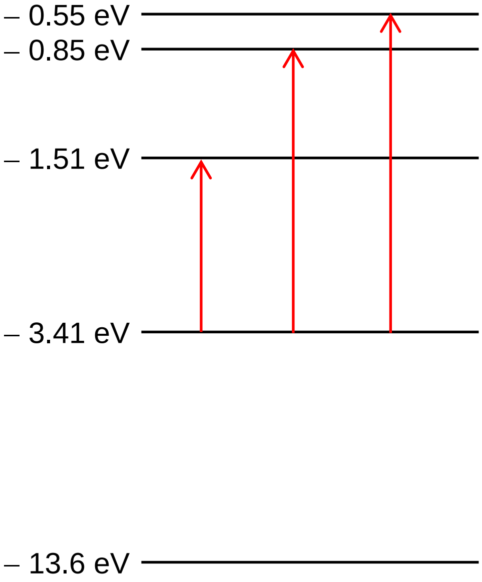
Qns	Answer	Marks
4(a)(i)	current in solenoid produces magnetic field with field lines parallel to axis of solenoid radii of copper disc cuts magnetic flux as it rotates, (by Faraday's law) rate of change of magnetic flux linkage results in emf	**1** **1** **1**
4(a)(ii)	consider a radial strip of copper: by faraday's law: $\lvert E\rvert = \frac{\mathrm{d}}{\mathrm{dt}}(N\phi) = \frac{\mathrm{d}}{\mathrm{dt}}(NBA)$ $= (1)(B)\frac{\mathrm{d}}{\mathrm{dt}}\left(\frac{1}{2}R^2\theta\right)$ $= \frac{1}{2}BR^2\omega$ $= \frac{1}{2}BR^2(2\pi f)$ $= BAf$	**1** **1**
4(b)(i)	at null deflection, p.d. across resistor = induced e.m.f. $V_R = E$ $IR = BAf$ $= (\mu_0 nI)Af$ same current in solenoid and resistor BUT NOT COPPER (disc/axle) $R = \mu_0 nAf$	**1**
4(b)(ii)	no electrical quantities needed so not dependent on accuracy of any voltmeter, ammeter or ohmmeter used	**1**
4(c)	$BAf = (\mu_0 nI)Af \quad \_\_(1)$ $R = \mu_0 nAf \quad \_\_(2)$ take $\frac{(1)}{(2)}$: $\frac{BAf}{R} = \frac{(\cancel{\mu_0 n}I)\cancel{Af}}{\cancel{\mu_0 n}\ \cancel{Af}}$ $B = \frac{IR}{AF} = \frac{(1.0\times10^{-3})(10)}{(\pi(0.20^2))(5.0)}$ $= 0.0159\ \text{T}$	**1**

Qns	Answer	Marks
5(a)	$hf = \Phi + \frac{1}{2}mv_{\text{max}}^2$ $= \Phi + eV_s$ $V_s = \left(\frac{h}{e}\right)f - \frac{\Phi}{e}$ when $V_s = 0$, $f = \frac{\Phi}{h}$ $= \frac{2.4\left(1.6\times10^{-19}\right)}{6.63\times10^{-34}} = 5.79\times10^{14}\text{ Hz}$ when $f = 0$, $V_s = -\frac{\Phi}{e}$ $= -\frac{2.4\text{ eV}}{e} = -2.4\text{ V}$ (extrapolated) 	**1** cut x-axis at (5.8, 0) **1** dotted line to (0, –2.4) **OR** pass through (8, 0.9)
5(b)	$V_{\text{peak, supply}} = \sqrt{2}\,V_{\text{supply, rms}}$ $= \sqrt{2}(4.6) = 6.5\text{ V}$ $V_{\text{peak, diode}} = V_{\text{peak, supply}}$ $= 6.5\text{ V}$	**1**

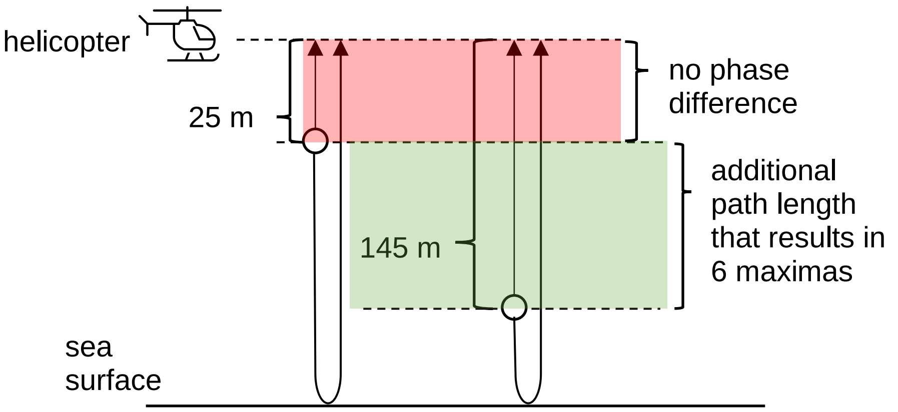
Qns	Answer	Marks
5(c)		1

Qns	Answer	Marks
6(a)(i)	time spent between plates: $t=\frac{L}{v}=\frac{10\times10^{-2}}{6.5\times10^{5}}=1.54\times10^{-7}\text{ s}$ $F=qE=ma$ $a=\frac{qE}{m}=\frac{q\Delta V}{md}=\frac{\left(1.6\times10^{-19}\right)(500)}{\left(1.67\times10^{-27}\right)\left(4.0\times10^{-2}\right)}=1.20\times10^{12}\text{ m s}^{-2}$ $v_{\perp}=u+at=0+at$ $=1.84\times10^{5}\text{ m s}^{-1}$ $\text{speed}=\sqrt{v_{\perp}^{2}+v_{\text{initial}}^{2}}$ $=6.76\times10^{5}\text{ m s}^{-1}\ \left(\text{accept }6.8\times10^{5}\text{ m s}^{-1}\right)$	1 1 1 1
6(a)(ii)	consider potential change from 0V equipotential line: $W=q\Delta V$ $\Delta V=\frac{\frac{1}{2}m_{p}v_{\perp}^{2}}{e}=177\text{ V}$ Potential is – 177 V as protons will displace towards region of lower potential OR consider displacement from 0V equipotential line: $s_{\perp}=ut+\frac{1}{2}at^{2}$ $=0+\frac{1}{2}\left(\frac{\left(1.6\times10^{-19}\right)(500)}{\left(1.67\times10^{-27}\right)\left(4.0\times10^{-2}\right)}\right)\left(\frac{10\times10^{-2}}{6.5\times10^{5}}\right)^{2}$ $=0.0141\text{ m}$ $V=\frac{s_{\perp}}{2.0\text{ cm}}(250)=177\text{ V}$ Potential is – 177 V as protons will displace towards region of lower potential	1 1 1

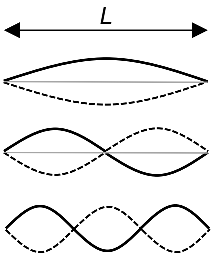
Qns	Answer	Marks
6(b)		
6(c)	uniform magnetic field (where field lines) pointing upwards	**1**
	no deviation for particles with velocity that result in equal **magnitudes** of electric and magnetic force	**1**
	acting in opposite **directions**	**1**

Qns	Answer	Marks
7(a)	a photon is a discrete packet of energy of electromagnetic radiation the energy of one photon is directly proportional to the frequency of electromagnetic radiation, $E = hf$	1
7(b)(i)	$E_{max} = \frac{hc}{\lambda_{min}} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(400\times10^{-9})(1.60\times10^{-19})} = 3.11\text{ eV}$ $E_{min} = \frac{hc}{\lambda_{max}} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(700\times10^{-9})(1.60\times10^{-19})} = 1.78\text{ eV}$	1
7(b)(ii)	The absorbed wavelengths are remitted in all directions; only part of the absorbed wavelengths is in the direction of the beam. These wavelengths appeared as dark lines with very much reduced intensities in the observed spectrum.	1
7(b)(iii)	 • Correct identification of the 3 possible transitions in the visible light range and nothing else (possible for electrons to start from *n* = 2 since question did not state cool gas) $E_{2\to3}$: 1.89 eV $E_{2\to4}$: 2.55 eV $E_{2\to5}$: 2.86 eV • Arrows pointing UP (absorption spectrum)	1 1
7(c)(i)	photons of visible light has <u>insufficient energy</u> to cause any transition of the electron from the lowest energy level. no dark band observed	1 1

Qns	Answer	Marks
7(c)(ii)1.	The 3 transitions for the 3 bright lines observed are: $E_{3\to2}$:1.89 eV $E_{4\to2}$:2.55 eV $E_{5\to2}$:2.86 eV Hence energy given to the electron must be from $E_{1\to5}$ so that the 3 transitions within the visible light spectrum can take place. $E_{1\to5} = 13.6 - 0.54 = 13.1\text{ eV}$ Hence V = 13.1 V	 **1** **1**
7(c)(ii)2.	$\lambda = \frac{hc}{E_{5\to2}}$ $= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(2.86)(1.60\times10^{-19})}$ $= 4.35\times10^{-7}$ m	**1**

Qns	Answer	Marks
8(a)(i)	when two or more waves meet and overlap, resultant displacement is vector sum of displacement of each individual wave	**1**
8(a)(ii)1.	waves from emitter directly and after reflecting off the sea surface meet and overlap at receiver/helicopter different path lengths as emitter drops so waves arrive at receiver/helicopter changing phase difference maxima when waves arrive in phase and undergo constructive interference minima when waves arrives in anti-phase and undergo destructive interference	**1** **1** **1**
8(a)(ii)2.	(words to effect of) attenuation of waves increase with distance from emitter / waves have lower intensity at greater distance from emitter / are of lower amplitude at greater distance from emitter (words to effect of) when emitter is near helicopter, amplitude/intensity of reflected wave is lower OR reflected wave is more attenuated than wave reaching directly so incomplete destructive interference OR (words to effect of) when emitter is near water surface, path length of both waves reaching helicopter directly and reflected wave is similar. so waves reach helicopter with similar intensity / amplitude / attenuation, resulting in more complete destructive interference	**1** **1**
8(a)(iii)	(words to effect of) 6 maximas between *d* = 25 m and *d* = 145m (words to effect of) distance between adjacent maxima is half wavelength $6\left(\frac{\lambda}{2}\right)=145-25$ $\lambda = 40$ m 	**1** **1** **1**
8(b)(i)	splitting of a single heavy nucleus when bombarded by neutrons to form two or more lighter nuclei of approximately same mass with neutrons emitted	**1**
8(b)(ii)	spontaneous and random emission of ionizing radiation in the form of alpha particles, beta particles or gamma ray photons from unstable nucleus to become a more stable nucleus	**1**

Qns	Answer	Marks
8(b)(iii)	combining of two or more light nuclei under very high temperatures to form a single, more massive nucleus	**1**
8(c)(i)	allows values of different orders of magnitude to be shown on one graph / along one axis	**1**
8(c)(ii)	[answer deals with conservation of mass in the form of nucleon number]	
	fission results in two daughter nuclei and two neutrons of total nucleon number 236 $${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{117+x}_{92-y}\mathrm{A} + {}^{117-x}_{y}\mathrm{B} + 2\,{}^{1}_{0}\mathrm{n}$$	**1**
	if same mass, each product has nucleon number of 117 $\left(= \frac{1}{2}(236-2) \right)$	**1**
	if one fission product has a nucleon number less than 117, the other fission product have the same difference in nucleon number above 117	**1**
	therefore symmetrical about 117	**A0**
8(d)(i)	${}^{140}_{53}\mathrm{I} \rightarrow {}^{139}_{53}\mathrm{I} + {}^{1}_{0}\mathrm{n}$	**1**
8(d)(ii)	${}^{140}_{53}\mathrm{I} \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e} \quad \left(+\bar{\nu}\right)$	**1**
8(d)(i)	energy released = [(total mass of reactant) – (total mass of product)] uc^2 $\left.\begin{aligned} &= \left[139.9019 - (138.8969 + 1.0087)\right] uc^2 \\ &= -0.0037uc^2 \text{ OR } -5.58 \times 10^{-13} \text{ J OR } -3.49 \times 10^{6} \text{ eV} \end{aligned}\right\}$ not feasible	**1**
8(d)(i)	energy released = [(total mass of reactant) – (total mass of product)] uc^2 $\left.\begin{aligned} &= \left[139.9019 - (139.8919 + 0.0006)\right] uc^2 \\ &= 0.0094uc^2 \text{ OR } 1.40 \times 10^{-12} \text{ J OR } 8.75 \times 10^{6} \text{ eV} \end{aligned}\right\}$ feasible	**1**

Qns	Answer	Marks
9(a)(i)	[source of force] wire experiences magnetic force directed normal to both current and magnetic field [property of vibration] alternating current so direction of force oscillates between vertically upwards and downwards	**1** **1**
9(a)(ii)1.	$v = f\lambda = (50)\left(2\times\left(40\times10^{-2}\right)\right) = 40\text{ m s}^{-1}$	**1**
9(a)(ii)2.	wave of same type, same frequency, same speed, (same amplitude) are reflected off fixed ends X and P and travel towards each other in opposite directions waves superpose along length XP speed is that (of energy transfer) of individual/constituent incident / reflected wave in wire	**1** **1** **1** **1**
9(a)(ii)3.	natural frequency of wire changes and no longer matches driving frequency from alternating current wire no longer in resonance so amplitude decrease	**1** **1**
9(a)(ii)4.	$L = \lambda_1$ $f_1 = \dfrac{v}{\lambda_1} = \dfrac{40}{40\times10^{-2}} = 100\text{ Hz}$ $L = \dfrac{3}{2}\lambda_2$ $f_2 = \dfrac{v}{\lambda_2} = \dfrac{40}{\left(\dfrac{2}{3}\right)40\times10^{-2}} = 150\text{ Hz}$  	**1**
9(b)(i)	$A = A_o\exp(-\lambda t)$ $\ln A = \ln A_o - \lambda t$ The gradient of the ln (*A* /s^{-1}) against t graph will give the value for -λ. ln (*A* /s^{-1}) in 1990 = 16.80; ln (*A* /s^{-1}) in 1997 = 16.20 $\text{gradient} = \dfrac{y_1 - y_2}{x_1 - x_2} = \dfrac{16.20 - 16.80}{7} = -0.0857\text{ y}^{-1}$ $\lambda = 2.72\times10^{-9}\ s^{-1}$	**1** **1**
9(b)(ii)	$T_{½} = \dfrac{\ln 2}{\lambda}$ $T_{½} = \dfrac{\ln 2}{2.72\times10^{-9}} = 2.55\times10^{8}\text{ s}$ $= 8.1\ yr$	**1** **1**

Qns	Answer	Marks
9(b)(iii)	At year 1997, ln (A / s^{-1}) = 16.20 A = e$^{16.20}$ = 1.10 x 10^{7} s^{-1}. The number of nuclei which ought to be present is $N_1 = \frac{A}{\lambda} = \frac{1.10 \times 10^{7}}{2.718 \times 10^{-9}}$ $= 4.00 \times 10^{15}$	**1** **1**
9(b)(iv)	The number of nuclei left after the theft is $N_2 = \frac{A}{\lambda} = \frac{e^{15.92}}{2.718 \times 10^{-9}} = 3.02 \times 10^{15}$ The number of nuclei stolen is given by $4.00 \times 10^{15} - 3.02 \times 10^{15} = 0.975 \times 10^{15}$	**1** **1**
9(b)(v)	gradient corresponds to the (magnitude of) decay constant decay constant is <u>not dependent on the number of radioactive nuclei</u> but is <u>characteristic/unique</u> to a particular nuclide	**1** **1**