GradeMax

Pearson

Mark Scheme (Results)

January 2026

Pearson Edexcel International Advanced Level in Physics
Paper 01: Thermodynamics, Radiation, Oscillations and Cosmology

WPH15/01

GradeMax

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. **It is not a set of model answers.**

1. Mark scheme format

1.1 You will not see 'wtte' (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. 'resonance'

1.2 Bold lower case will be used for emphasis e.g. '**and**' when two pieces of information are needed for 1 mark.

1.3 Round brackets ( ) indicate words that are not essential e.g. "(hence) distance is increased".

1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.

2.2 This does not apply in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.

2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.

2.5 The mark scheme will indicate if no unit error is to be applied by placing brackets around the unit.

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not prevent a mark being awarded if the answer given rounds to the answer in the MS.

3.2 Too few significant figures will mean that the final mark cannot be awarded in 'show that' questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.

3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.

3.4 The use of $g = 10\ \text{m s}^{-2}$ or $10\ \text{N kg}^{-1}$ instead of $9.81\ \text{m s}^{-2}$ or $9.81\ \text{N kg}^{-1}$ will be penalised by one mark (but not more than once per clip). Accept $9.8\ \text{m s}^{-2}$ or $9.8\ \text{N kg}^{-1}$

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 **use of** the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.

4.2 If a 'show that' question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.

4.3 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Expression

5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.

5.2 Marks are awarded for indicative content and for how the answer is structured.

5.3 Linkage between ideas, and fully-sustained reasoning is expected.

Question Number	Answer	Mark
1	**The only correct answer is D** (subtract the background count rate) A is not correct because the background count rate must be subtracted B is not correct because the background count rate must be subtracted C is not correct because the background count rate must be subtracted	1
2	**The only correct answer is B** (It can undergo significant plastic deformation.) A is not correct because this describes an elastic material C is not correct because this describes a strong material D is not correct because this describes a stiff material	1
3	**The only correct answer is A** ($\mathrm{W\,m^{-2}}$) B is not correct because this is an equivalent unit for energy C is not correct because this is an equivalent unit for luminosity D is not correct because this is an equivalent unit for force	1
4	**The only correct answer is C** (the distance to X is 0.5 times the distance to Y) A is not correct because Star X would have a quarter the parallax angle of Star Y B is not correct because Star X would have half the parallax angle of Star Y D is not correct because Star X would have four times the parallax angle of Star Y	1
5	**The only correct answer is B** (The average density of the universe is less than the critical density of the universe.) A is not correct because this would be a flat universe C is not correct because density rather than mass determines the type of universe D is not correct because density rather than mass determines the type of universe	1

Question Number	Answer	Mark
6	**The only correct answer is C** (We cannot influence when the decay will occur.) A is not correct because a natural process can be random or spontaneous or both B is not correct because this means when the next decay occurs can't be predicted D is not correct because this describes a random process	**1**
7	**The only correct answer is A** $\left(\frac{1}{4}\right)$ B is not correct because $I \propto \frac{1}{d^2}$ C is not correct because $I \propto \frac{1}{d^2}$ D is not correct because $I \propto \frac{1}{d^2}$	**1**
8	**The only correct answer is B** (80 counts per minute) A is not correct because this would be the count rate for 5 mm C is not correct because this would be the count rate for 2.5 mm D is not correct because this would be the count rate for 2 mm	**1**
9	**The only correct answer is D** (G, O, M, A) A is not correct because hot and cool giant stars as well as hot and cool dwarf stars are mixed up B is not correct because hot and cool giant stars are mixed up C is not correct because hot and cool dwarf stars are mixed up	**1**
10	**The only correct answer is D** (Some energy was transferred to the ice from the surroundings.) A is not correct because this would give a value for L > the accepted value B is not correct because this would give a value for L > the accepted value C is not correct because this would give a value for L > the accepted value	**1**

Question Number	Answer		Additional Guidance	Mark
11	Use of $\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$	**(1)**	Allow 508 ($\times 10^{-9}$) in the denominator for MP1 only Allow use of $z = \frac{\Delta f}{f}$ **and** $z = \frac{v}{c}$	**2**
	$v = 1.36 \times 10^7\ \text{m s}^{-1}$	**(1)**	Example of calculation $\frac{v}{3.00 \times 10^8\ \text{m s}^{-1}} \approx \frac{(508 - 486) \times 10^{-9}\ \text{m}}{486 \times 10^{-9}\ \text{m}}$ $v = \frac{3.00 \times 10^8\ \text{m s}^{-1} \times (508 - 486) \times 10^{-9}\ \text{m}}{486 \times 10^{-9}\ \text{m}} =$ $\therefore v = 1.358 \times 10^7\ \text{m s}^{-1}$	
	Total for question 11			**2**

Question Number	Answer		Additional Guidance	Mark
12	Use of $\Delta E = mc\Delta\theta$	**(1)**	Substitution for $\Delta\theta$ must be a temperature difference Ignore attempt to convert to kelvin for this marking point	**2**
	$\Delta E = 1.2 \times 10^4\ \text{J}$	**(1)**	Example of calculation $\Delta E = 0.21\ \text{kg} \times 4.18 \times 10^3\ \text{J kg}^{-1}\ \text{K}^{-1} \times (27.5 - 18.2)\ \text{K}$ $+ 0.095\ \text{kg} \times 4180\ \text{J kg}^{-1}\ \text{K}^{-1} \times (27.5 - 18.2)$ $\Delta E = 8.16 \times 10^3\ \text{J} + 3.69 \times 10^3\ \text{J}$ $= 1.19 \times 10^4\ \text{J}$	
	Total for question 12			**2**

Question Number	Answer	Additional Guidance	Mark
13	Number of nitrogen molecules calculated **(1)** Use of $pV = NkT$ **(1)** Conversion of temperature to K **(1)** $V = 7.4 \times 10^{-2}\text{m}^3$ **(1)**	 Accept temperature in Celsius Accept use of 273.15 [Calculation done in one step gives $V = 7.41 \times 10^{-2}\text{m}^3$] <u>Example of calculation</u> $N = \frac{0.0875\text{ kg}}{4.67 \times 10^{-26}\text{ kg}} = 1.87 \times 10^{24}$ $V = \frac{NkT}{p} = \frac{1.87 \times 10^{24} \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times (22 + 273)\text{ K}}{1.03 \times 10^{5}\text{ Pa}}$ $V = 7.39 \times 10^{-2}\text{m}^3$	**4**
	Total for question 13		**4**

Question Number	Answer	Additional Guidance	Mark
14(a)	Both processes result in an increase in binding energy (per nucleon) **(1)** Energy released equals increase in binding energy per nucleon multiplied by number of nucleons **(1)** But uranium has many more nucleons, (so total energy released is much greater) **(1)**		**3**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*14(b)</td><td>
Indicative content

IC1 There must be a (very) high temperature (in the core)

IC2 To give nuclei/protons large/enough kinetic energy [accept K.E. or E_k]

IC3 So that nuclei/protons get close enough to fuse

IC4 There is an electrostatic repulsion between nuclei/protons
Or Nuclei/protons all have a positive charge and repel

IC5 There must be a (very) high density

IC6 To give a high collision rate (to maintain fusion)
Or To give a high collision rate to maintain high temperature

[IC3: accept reference to close enough for strong force to act]

[IC5 allow “a (very) high pressure”]

[In IC2 – IC4 there must be a reference to nuclei/protons. If atoms/particles/molecules instead of nuclei/protons used, then do not credit the first IC point seen. However, allow credit for any subsequent references to atoms/particles/molecules instead of nuclei/protons]
</td><td>
This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
<table>
<tr><td colspan="2">Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td>6</td></tr>
<tr><td></td><td>Total for question 14</td><td></td><td>9</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
15(a)	Use of $T = 2\pi\sqrt{\frac{l}{g}}$ **(1)** $T = 1.62$ (s) **(1)**	minimum 3 sig figs Example of calculation $T = 2\pi\sqrt{\frac{0.65\text{ m}}{9.81\text{ N kg}^{-1}}} = 1.617\text{ s}$	**2**
15(b)	Use of $\omega = \frac{2\pi}{T}$ **(1)** Use of $v = \omega A \sin \omega t$ with $\sin \omega t = 1$ **(1)** Use of $E_k = \frac{1}{2}mv^2$ **(1)** $E_{k,max} = 4.5 \times 10^{-4}$ J (ecf from (a)) **(1)**	Allow A = 2.5 cm, 1.25 cm or 5.0 cm for this MP Use of 'show that' value gives 4.6×10^{-4} J Calculation done in one step gives 4.6×10^{-4} J Example of calculation $\omega = \frac{2\pi}{1.62\text{ s}} = 3.88\text{ rad s}^{-1}$ $v = 3.88\text{ rad s}^{-1} \times 2.5 \times 10^{-2}\text{ m} \times 1$ $= 0.0970\text{ m s}^{-1}$ $E_{k,max} = \frac{1}{2} \times 9.5 \times 10^{-2}\text{ kg} \times (0.0970\text{ m s}^{-1})^2$ $= 4.47 \times 10^{-4}$ J	**4**
	Total for question 15		**6**

Question Number	Answer		Additional Guidance	Mark
16	**EITHER**			
	Volume of evaporated water calculated	**(1)**	Accept initial volume of water	
	Use of $\rho = \frac{m}{V}$	**(1)**		
	L read from graph in range 2.33 ($\times 10^6$ J kg^{-1}) to 2.35 ($\times 10^6$ J kg^{-1})	**(1)**		
	Use of $\Delta E = L\Delta m$	**(1)**		
	m = 6400 kg	**(1)**	Unit essential	
	6000 (kg) ≠ 6400 (kg) so information is not accurate **Or** Comparison of calculated m with 6000 (kg) and consistent conclusion	**(1)**		
	OR			
	Volume of evaporated water calculated	**(1)**	Accept initial volume of water	
	Use of $\rho = \frac{m}{V}$	**(1)**		
	L read from graph in range 2.33 ($\times 10^6$ J kg^{-1}) to 2.35 ($\times 10^6$ J kg^{-1})	**(1)**		
	Use of $\Delta E = L\Delta m$ to find energy required to evaporate water	**(1)**		
	Calculate energy supplied from burning coal	**(1)**	[1.44×10^5MJ]	
	Energy supplied, 1.4×10^5MJ $< 1.5 \times 10^5$MJ so information is not accurate	**(1)**	Unit essential for at least one of the energy values. <u>Example of calculation</u> $V = 24\text{ m} \times 9.1\text{ m} \times 0.25\text{ m} = 54.6\text{ m}^3$ $m = \rho V = 1200\text{ kg m}^{-3} \times 54.6\text{ m}^3$ $= 6.55 \times 10^4\text{ kg}$ $\Delta E = 6.55 \times 10^4\text{ kg} \times 2.34 \times 10^6\text{ J K}^{-1}$ $= 1.53 \times 10^{11}\text{ J}$ $\Delta m = \frac{1.53 \times 10^{11}\text{ J}}{24 \times 10^6\text{ J kg}^{-1}} = 6380\text{ kg}$	**6**
	Total for question 16			**6**

Question Number	Answer	Additional Guidance	Mark
17(a)	Dark matter exerts a gravitational force **Or** Dark matter has mass **(1)** Dark matter does not emit electromagnetic radiation **(1)**	Do not accept light for electromagnetic radiation.	**2**
17(b)	**EITHER** $\frac{GMm}{r^2}$ equated to $m\omega^2 r$ **(1)** Use of $\omega = \frac{2\pi}{T}$ **(1)** Use of $r = 420 \times 10^3 + 6.4 \times 10^6$ (m) **(1)** Use of $f = \frac{1}{T}$ **(1)** number of complete orbits in 1 day = 15 (whole number only) **(1)** **OR** $\frac{GMm}{r^2}$ equated to $\frac{mv^2}{r}$ **(1)** Use of $v = \frac{2\pi r}{T}$ **(1)** Use of $r = 420 \times 10^3 + 6.4 \times 10^6$ (m) **(1)** Use of $f = \frac{1}{T}$ **(1)** number of complete orbits in 1 day = 15 (whole number only) **(1)** [If a version of the Kepler equation has been memorised and used to give the correct value for the number of orbits, give full credit. If the wrong number of orbits, then only MP3 and MP4 are available]	Example of calculation $\frac{GMm}{r^2} = m\omega^2 r$ $\omega = \sqrt{\frac{GM}{r^3}} = \sqrt{\frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6.0 \times 10^{24}\ \text{kg}}{(6.4 \times 10^6 \text{m} + 4.2 \times 10^5 \text{m})^3}}$ $= 1.12 \times 10^{-3}\ \text{rad s}^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi}{1.12 \times 10^{-3}\ \text{rad s}^{-1}} = 5.59 \times 10^3\ \text{s}$ $T = \frac{5.59 \times 10^3\ \text{s}}{86\,400\ \text{s day}^{-1}} = 6.47 \times 10^{-3}\ \text{day}$ Number of orbits per day= $\frac{1}{T} = \frac{1}{6.47 \times 10^{-3}\ \text{day}} = 15.46\ \text{day}^{-1}$	**5**

Question Number	Answer		Additional Guidance	Mark
17(c)	**EITHER** Weight is mass multiplied by gravitational field strength	**(1)**	Accept W= mg	**4**
	The astronauts/ISS close to the Earth **Or** Astronauts/ISS not far away from the Earth	**(1)**		
	A gravitational force acts on the astronauts **Or** gravitational field strength is not zero **Or** astronauts are in a gravitational field	**(1)**	Accept *g* for gravitational field strength	
	Astronauts have weight and the statement is not valid MP4 dependent upon MP3	**(1)**		
	OR			
	The astronauts are orbiting the Earth **Or** Astronauts experience a centripetal acceleration/force	**(1)**		
	(So) there must be a resultant force acting on the astronauts	**(1)**		
	Therefore there must be a gravitational force	**(1)**		
	Astronauts have weight, and the statement is not valid MP4 dependent upon MP3	**(1)**		
	OR			
	Use of $g = \frac{GM}{r^2}$	**(1)**		
	Use of $r = 420 \times 10^3 + 6.4 \times 10^6$ (m)	**(1)**		
	g = 8.6 N/kg	**(1)**		
	$g \neq 0$ so astronauts have weight and statement is not valid MP4 dependent upon MP3	**(1)**		
	Total for question 17			**11**

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	**EITHER** Use of $L = \sigma A T^4$ **(1)** Use of $A = 4\pi r^2$ **(1)** Ratio of radii = 12% **(1)** $12(\%) \approx 10(\%)$, so star is a typical red dwarf star **Or** Comparison of calculated value with 10% **and** consistent conclusion. **(1)** **OR** Use of $L = \sigma A T^4$ **(1)** Use of $A = 4\pi r^2$ **(1)** Calculates 10% r_{Sun} **(1)** 8.3×10^7 m $> 7.0 \times 10^7$ m so not a typical red dwarf star **(1)**	Accept $12(\%) > 10(\%)$ so not a typical red dwarf star Accept $12(\%) \neq 10(\%)$ so not a typical red dwarf star **For MP4** Accept 8.3×10^7 m $\neq 7.0 \times 10^7$m so not a typical red dwarf star Accept 8.3×10^7 m $\approx 7.0 \times 10^7$m so is a typical red dwarf star Example of calculation $A = \frac{L}{\sigma T^4} = \frac{2.13 \times 10^{23}\ \text{W}}{5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4} \times (2570\ \text{K})^4} = 8.61 \times 10^{16}\ \text{m}^2$ $r = \sqrt{\frac{8.61 \times 10^{16}\ \text{m}^2}{4\pi}} = 8.28 \times 10^7\ \text{m}$ $\frac{r}{r_{\text{sun}}} = \frac{8.28 \times 10^7\ \text{m}}{6.96 \times 10^8\ \text{m}} = 0.119$ $12\% \approx 10\%$, so star is a typical red dwarf star	**4**

Question number	Answer	Additional Guidance	Mark
18(a)(ii)	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K **(1)** $\lambda_{max} = 1.13 \times 10^{-6}$ (m) **(1)**	Minimum 3 sig figs Example of calculation $\lambda_{max} = \frac{2.898 \times 10^{-3}\text{ m K}}{2570\text{ K}} = 1.13 \times 10^{-6}\text{ m}$	**2**
18(a)(iii)	λ_{max} > 750 nm **Or** 1.1×10^{-6} m is in the IR region of the em-spectrum **(1)** But there will be visible light mostly in the red region of the spectrum **(1)**	Accept 1.1×10^{-6} m > 750 nm	**2**
18(b)(i)	Use of $g = \frac{GM}{r^2}$ **(1)** gravitational field strength $= 8.0$ N kg^{-1} **(1)**	Accept m s^{-2} Example of calculation $g = \frac{6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 4.15 \times 10^{24}\text{ kg}}{(0.92 \times 6.4 \times 10^6\text{m})^2}$ $= 7.98$ N kg^{-1}	**2**
18(b)(ii)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ **(1)** Mean kinetic energy $= 4.9 \times 10^{-21}$ J **(1)**	Example of calculation $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2} \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times 235\text{ K}$ $= 4.86 \times 10^{-21}$ J	**2**

Question number	Answer	Additional Guidance	Mark
18(b)(iii)	(As temperature increases) the (mean) K.E. of the molecules increases **(1)** More molecules will have enough energy to escape from the planet **Or** More molecules will have a velocity that exceeds escape velocity **Or** Molecules may spread out **(1)**	Do not accept particles for molecules in MP1 Accept volume occupied by molecules increases [Do not accept charged particles for either MP]	**2**
	Total for question 18		**14**

Question Number	Answer		Additional Guidance	Mark
19(a)(i)	Mass difference calculated	**(1)**		**5**
	Conversion between u and kg	**(1)**	[Do not accept use of 1.67×10^{-27}]	
	Use of $\Delta E = c^2 \Delta m$	**(1)**		
	Conversion between J and (M)eV	**(1)**		
	$\Delta E = 7.88$ (MeV)	**(1)**	No intermediate rounding → 7.85 MeV <u>Example of calculation</u> $\Delta m = (213.995186 - 209.984173 - 4.002603)\text{u}$ $= 8.41 \times 10^{-3}$ u $\Delta m = 8.41 \times 10^{-3}\ \text{u} \times 1.66 \times 10^{-27}\text{kg u}^{-1}$ $= 1.40 \times 10^{-29}$ kg $\Delta E = (3.0 \times 10^{8}\ \text{m s}^{-1})^2 \times 1.40 \times 10^{-29}$ kg $= 1.26 \times 10^{-12}$ J $\Delta E = \dfrac{1.26 \times 10^{-12}\ \text{J}}{1.6 \times 10^{-13}\ \text{J MeV}^{-1}} = 7.88\ \text{MeV}$	
19(a)(ii)	Momentum must be conserved (in the decay)	**(1)**		**2**
	(So recoiling) lead nucleus has <u>kinetic</u> energy	**(1)**	Accept K.E. or E_k	

Question Number	Answer		Additional Guidance	Mark
19(b)(i)	Top line correct Bottom line correct $^{210}_{82}\text{Pb} \rightarrow {}^{210}_{83}\text{Bi} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_{e}$	**(1)** **(1)**		**2**
19(b)(ii)	Use of $\lambda t_{1/2} = \ln 2$ Use of $A = A_0 e^{-\lambda t}$ $t = 119$ year (for activity to decrease to 2.5% A_0) **Or** $A = 4.5\%\ A_0$ (after 100 year) 119 years > 100years so textbook is not correct **Or** 4.5% > 2.5% so textbook is not correct **Or** Comparison of calculated value with value given in question and appropriate conclusion made	**(1)** **(1)** **(1)** **(1)**	Example of calculation $\lambda = \dfrac{\ln 2}{22.3 \text{ year}} = 3.11 \times 10^{-2} \text{ year}^{-1}$ $0.025 = e^{-3.11 \times 10^{-2} \times t}$ $\therefore t = \dfrac{\ln(0.025)}{-3.11 \times 10^{-2} \text{ year}^{-1}} = 119 \text{ year}$	**4**
19(c)	Alpha particles are very ionising If breathed in can cause damage to (living) cells	**(1)** **(1)**		**2**
	Total for question 19			**15**

Question Number	Answer		Additional Guidance	Mark
20(a)(i)	Corresponding values of V_{grav} and r read from graph Use of $V_{grav} = (-)\frac{GM}{r}$ M in range 6.42×10^{23} (kg) → 6.44×10^{23} (kg) (at least 3 sf)	**(1)** **(1)** **(1)**	Example of calculation $r = 3.5 \times 10^6$ m; $V_{grav} = -12.25 \times 10^{12}$ J kg^{-1} $M = \frac{-r\,V_{grav}}{M} = \frac{3.5 \times 10^6 \text{ m} \times 12.25 \times 10^6 \text{ J kg}^{-1}}{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}}$ $= 6.428 \times 10^{23}$ kg	**3**
20(a)(ii)	**EITHER** Values of potential read from graph for start and end positions Determine ΔE_{grav} using $\Delta V_{grav} \times m$ $\Delta E_{grav} = 1.4 \times 10^8$ J **OR** Use of $\Delta V_{grav} = GM\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ with M = mass of Mars ecf value of M from (a)(i) Determine ΔE_{grav} using $\Delta V_{grav} \times m$ $\Delta E_{grav} = 1.6 \times 10^8$J	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	Example of calculation Initial distance = 124×10^3 m + 3.4×10^6 m = 3.52×10^6 m $\Delta E_{grav} = (-12.2 \times 10^6 + 12.6 \times 10^6)$ J kg^{-1} $\times$ 358 kg $= 1.43 \times 10^8$ J	**3**

Question Number	Answer	Additional Guidance	Mark
20(a)(iii)	**EITHER** Parachute exerts an upward/drag force **(1)** Terminal/landing velocity is smaller **(1)** (Rate of) change of momentum on impact is smaller **(1)** Impact force is reduced (so less damage) **(1)** **OR** Without parachute velocity would be very large **(1)** (Rate of) change of momentum on impact would be (very) high **(1)** Impact force would be large (and cause damage) **(1)** Parachute would exert upward/drag force so landing velocity would be smaller **(1)** **OR** There will be a large energy transfer from gravitational potential **(1)** Parachute exerts an upward/drag force **(1)** Work is done by upward/drag force so less transfer to kinetic energy **(1)** Spacecraft approaches surface with a lower velocity (so less damage) **(1)**		**4**
20(b)	The atmosphere (on Mars) is less dense **Or** The terminal velocity would be greater (on Mars) **Or** To increase the drag force (on Mars) **(1)**	Accept atmosphere is thinner (on Mars)	**1**
	Total for question 20		**11**