Pearson Edexcel

Mark Scheme (Results)

Summer 2021

Pearson Edexcel International Advanced Level in Physics (WPH15)
Paper 05 Thermodynamics, Radiation, Oscillations and Cosmology

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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.

For example:

(iii) <u>Horizontal force of hinge on table top</u>

66.3 (N) or 66 (N) and correct indication of direction [no ue] [Some examples of direction: acting from right (to left) / to the left / West / opposite direction to horizontal. May show direction by arrow. Do not accept a minus sign in front of number as direction.]	✓	1

This has a clear statement of the principle for awarding the mark, supported by some examples illustrating acceptable boundaries.

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. '<u>resonance</u>'
   - 1.2 Bold lower case will be used for emphasis.
   - 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 Incorrect use of case e.g. 'Watt' or 'w' will not be penalised.
   - 2.3 There will be no unit penalty applied in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.
   - 2.4 The same missing or incorrect unit will not be penalised more than once within one question (one clip in epen).
   - 2.5 Occasionally, it may be decided not to penalise a missing or incorrect 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.
   - 2.6 The mark scheme will indicate if no unit error penalty is to be applied by means of [no ue].

3. Significant figures
   - 3.1 Use of an inappropriate number of significant figures in the theory papers will normally only be penalised in 'show that' questions where use of too few significant figures has resulted in the candidate not demonstrating the validity of the given answer.
   - 3.2 The use of g = 10 m s^{-2} or 10 N kg^{-1} instead of 9.81 m s^{-2} or 9.81 N kg^{-1} will be penalised by one mark (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}

4. Calculations
   4.1 Bald (i.e. no working shown) correct answers score full marks unless in a ‘show that’ question.
   4.2 If a ‘show that’ question is worth 2 marks then both marks will be available for a reverse working; if it is worth 3 marks then only 2 will be available.
   4.3 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.
   4.4 recall of the correct formula will be awarded when the formula is seen or implied by substitution.
   4.5 The mark scheme will show a correctly worked answer for illustration only.
   4.6 Example of mark scheme for a calculation:

<u>‘Show that’ calculation of weight</u>

Use of L × W × H ✓

Substitution into density equation with a volume and density ✓

Correct answer [49.4 (N)] to at least 3 sig fig. [No ue] ✓
[If 5040 g rounded to 5000 g or 5 kg, do not give 3rd mark; if conversion to kg is omitted and then answer fudged, do not give 3rd mark]
[Bald answer scores 0, reverse calculation 2/3] 3

Example of answer:

$80\text{ cm} \times 50\text{ cm} \times 1.8\text{ cm} = 7200\text{ cm}^3$

$7200\text{ cm}^3 \times 0.70\text{ g cm}^{-3} = 5040\text{ g}$

$5040 \times 10^{-3}\text{ kg} \times 9.81\text{ N/kg}$

$= 49.4\text{ N}$

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.

6. Graphs
   6.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.
   6.2 Sometimes a separate mark will be given for units or for each axis if the units are complex. This will be indicated on the mark scheme.
   6.3 A mark given for choosing a scale requires that the chosen scale allows all points to be plotted, spreads plotted points over more than half of each axis and is not an awkward scale e.g. multiples of 3, 7 etc.
   6.4 Points should be plotted to within 1 mm.
   - Check the two points furthest from the best line. If both OK award mark.
   - If either is 2 mm out do not award mark.
   - If both are 1 mm out do not award mark.
   - If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.
   - For a line mark there must be a thin continuous line which is the best-fit line for the candidate’s results.

Question Number	Answer	Mark
1	**D is the correct answer** A is not the correct answer as the background is already included in the count B is not the correct answer as the background will still add a systematic error C is not the correct answer as the background will still add a systematic error	**(1)**
2	**B is the correct answer** A is not the correct answer as H_0 does not give the size of the universe C is not the correct answer as $1/H_0$ gives the age of the universe D is not the correct answer as H_0 does not give the size of the universe	**(1)**
3	**D is the correct answer** A is not the correct answer as damping occurs at all frequencies B is not the correct answer as energy is transferred at all frequencies C is not the correct answer as energy is dissipated at all frequencies	**(1)**
4	**D is the correct answer** A is not the correct answer as helium is not being fused in the Sun B is not the correct answer as fusion doesn't require a large number of H nuclei C is not the correct answer as fusion does not require a large mass of H	**(1)**
5	**B is the correct answer** as $g = \frac{GM}{r^2}$ and $M \propto \rho$ (as both have the same volume)	**(1)**
6	**A is the correct answer** B is not the correct answer as this would have a much lower temperature than the Sun C is not the correct answer as this would have a much higher luminosity than the Sun D is not the correct answer as this would have a much lower luminosity than the Sun	**(1)**
7	**C is the correct answer** A is not the correct answer as mean square velocity increases as the gas is heated B is not the correct answer as $p \propto T$, so T quadruples when p quadruples D is not the correct answer as $p \propto T$, so T quadruples when p quadruples	**(1)**
8	**D is the correct answer** as $L = \sigma A T^4$, so $L \propto T^4$ (as both have the same radius)	**(1)**
9	**B is the correct answer** as $v_{max} = \omega A$ and $\omega = \frac{2\pi}{T}$, so $v_{max} = \left(\frac{2\pi}{T}\right) \times A$	**(1)**
10	**A is the correct answer** B is not the correct answer as λ_{max} is less for X, so surface temperature is higher C is not the correct answer as the max intensity of X (hence luminosity) is higher D is not the correct answer as the max intensity of X (hence luminosity) is higher **and** λ_{max} for X is less, so surface temperature must be higher	**(1)**

Question Number	Answer	Mark
11(a)	The atoms/molecules make more frequent collisions with the glass tube **Or** The atoms/molecules have a higher rate of collision with the glass tube **Or** The atoms/molecules make more collisions per second with the glass tube (1) (Do not accept collisions between molecules) The rate of change of momentum of the atoms/molecules increases (1) The force exerted on the glass tube increases (1) (Pressure exerted by the gas increases) as pressure is force per unit area (1)	**4**
11(b)	Use of $pV = NkT$ (1) $N = 6.3 \times 10^{22}$ (1) <u>Example of calculation</u> $N = \frac{1.05 \times 10^{5}\text{ Pa} \times 2.43 \times 10^{-3}\text{ m}^3}{1.38 \times 10^{-23}\text{ J K}^{-1} \times 293\text{ K}} = 6.31 \times 10^{22}$	**2**
	Total for question 11	**6**

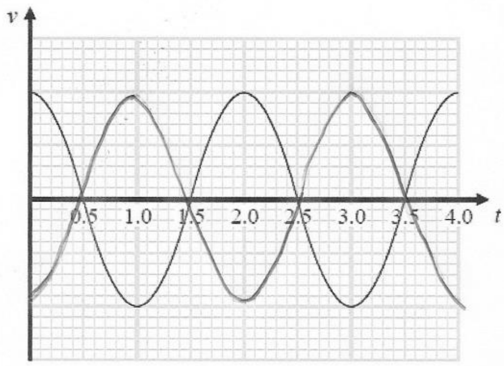
Question Number	Answer	Mark
12(a)	A standard candle is a (astronomical) object of known luminosity (1)	**1**
12(b)(i)	Use of $P = \frac{\Delta E}{\Delta t}$ (1) Use of $I = \frac{P}{A}$ (1) Use of $I = \frac{L}{4\pi d^2}$ (1) $L = 2.2 \times 10^{35}$ (W) (1) Example of calculation $P = \frac{9.40 \times 10^{-23}\ \text{J}}{1.15 \times 10^{-3}\ \text{s}} = 8.17 \times 10^{-20}\ \text{W}$ $I = \frac{8.17 \times 10^{-20}\ \text{W}}{1.00 \times 10^{-4}\ \text{m}^2} = 8.17 \times 10^{-16}\ \text{W m}^{-2}$ $L = 4\pi d^2 I = 4\pi \times (4.60 \times 10^{24}\ \text{m})^2 \times 8.17 \times 10^{-16} = 2.17 \times 10^{35}\ \text{W}$	**4**
12(b)(ii)	Source luminosity is much larger than the luminosity of the Sun **Or** source is equivalent to the combined output of many Suns **Or** $L_{FRB}/L_{Sun} \sim 5 \times 10^8$ (1) So such a large power output is unlikely to be artificially produced. (1) **Or** the temperature would be much greater than that of the Sun (so not likely to be artificially produced) [dependent on MP1] Response consistent with their calculated value in (b)(i)	**2**
	Total for question 12	**7**

Question Number	Answer	Mark
13	Use of $\rho = \frac{m}{V}$ (1) Use of $\Delta E = mc\Delta\theta$ (1) Use of $\Delta E = L\Delta m$ (1) Use of $P = \frac{\Delta E}{\Delta t}$ [to calculate time to melt completely] **Or** use of $P = \frac{\Delta E}{\Delta t}$ to calculate energy received from the Sun in 1 day (1) $t = 1.21 \times 10^5$ s or **Or** $\Delta E = 6.48 \times 10^{10}$ J (1) t = 33.7 hours, so palace would not melt completely in a day **Or** energy required is $9.09 \times 10^{10}\ J$, so more energy required than would be transferred in 1 day, so palace would not melt completely. (1) (Allow full credit for responses in which 1 day is 12 hours) <u>Example of calculation</u> $m = \rho V$=1325 kg m^{-3} ×1250 m^3=1.66×10^6 kg ΔE=1.66×10^6×1.30×10^3J kg^{-1}K^{-1}×(36.0-28.5) K = 1.62×10^{10} J $\Delta E = 4.5 \times 10^4$ J kg^{-1}×1.66×10^6 kg = 7.47×10^{10} J Energy required = 1.62×10^{10} J + 7.47×10^{10} J = $9.09 \times 10^{10}\ J$ $t = \frac{(1.62+7.47) \times 10^{10}\text{J}}{7.5 \times 10^5\text{ W}} = 1.21 \times 10^5$ s $t = \frac{1.21 \times 10^5\text{ s}}{3600\text{ s hour}^{-1}}$ =33.7 hour In 1 day, $\Delta E = 7.5 \times 10^5$ W ×24 ×3600 s = $6.48 \times 10^{10} J$	6
	Total for question 13	**6**

Question Number	Answer		Mark
14(a)(i)	Same time period as velocity **and** constant amplitude	(1)	
	Wave shifted a quarter cycle to the right [i.e. a positive sine wave, displacement is zero at time zero.]	(1)	2
14(a)(ii)	T = 2.0 s from graph	(1)	
	Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (accept any value of T that could be read from the graph)	(1)	
	$\ell = 0.99$ m	(1)	3
	<u>Example of calculation</u> $2.0\text{ s}=2\pi\sqrt{\frac{\ell}{9.81\text{ m s}^{-2}}}$ $\ell=\frac{(2.0\text{ s})^2\times9.81\text{ m s}^{-2}}{4\pi^2}=0.994\text{ m}$		
14(b)	**EITHER**		
	Suitable data logger application identified	(1)	
	Reason why data logger is an advantage in this situation	(1)	
	OR		
	Max 2 from		
	When data has to be collected over a very short time interval	(1)	
	When multiple data sets have to be collected simultaneously	(1)	
	When data has to be collected over a very long time interval	(1)	2
	Total for question 14		**7**

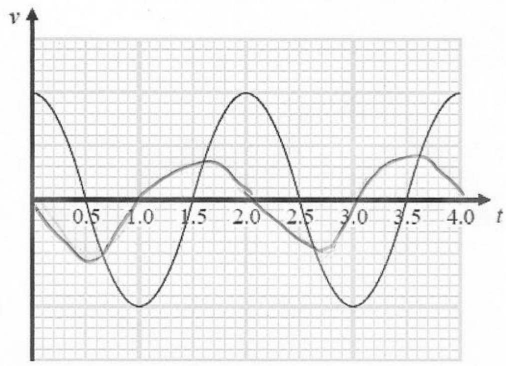
Q14(a)(i)

Examples of possible responses:



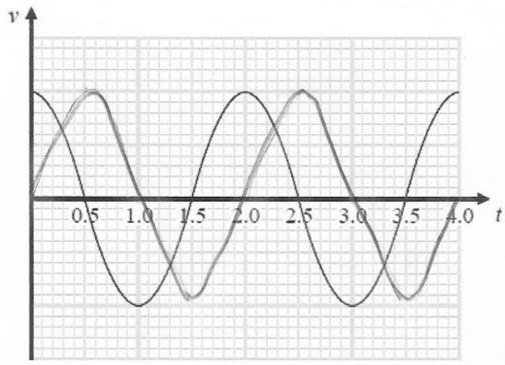
Response 1

MP1 only



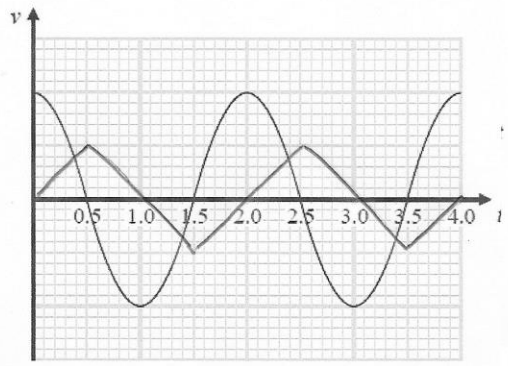
Response 2

No marks



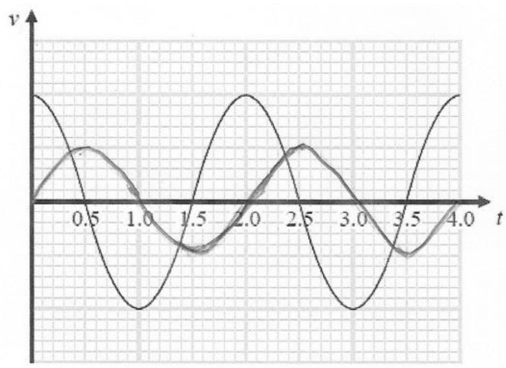
Response 3

MP1 & MP2



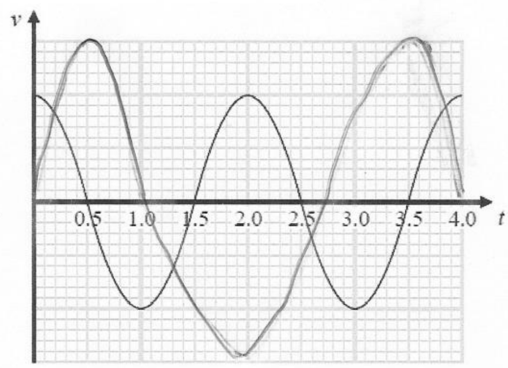
Response 4

MP1 only



Response 5

MP1 & MP2



Response 6

MP2 only

Question Number	Answer		Mark
15(a)	$\lambda_{max} = 0.37 \rightarrow 0.40$ (μm) Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $T = 7600$ K (accept answer consistent with their stated value of λ_{max}) <u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3} \text{ m K}}{0.38 \times 10^{-6} \text{ m}} = 7626$ K	(1) (1) (1)	**3**
15(b)	Corresponding pair of wavelengths recorded (one from each spectrum) Wavelength shift calculated [wavelengths may be out of range, but must be one from each spectrum] Use of $\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$ [value of λ must be taken from lab spectrum] $v = 1.5 \times 10^{7}$ m s^{-1} [v will depend upon in-range values used] Star is receding <u>Example of calculation</u> $\lambda_{star} = 654$ nm → 658 nm $\lambda_{lab} = 622$ nm → 626 nm **Or** $\lambda_{star} = 479$ nm **or** 480 nm $\lambda_{lab} = 452$ nm → 456 nm $v = 3.00 \times 10^{8} \text{ m s}^{-1} \times \frac{(656 \text{ nm} - 624 \text{ nm})}{624 \text{ nm}} = 1.54 \times 10^{7} \text{ m s}^{-1}$	(1) (1) (1) (1) (1)	**5**
	Total for question 15		**8**

Question Number	Answer	Mark
16(a)	**Either** Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ (1) Use of $\omega = \frac{2\pi}{T}$ (1) $T = 5800$ s (1) **Or** Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ (1) Use of $v = \frac{2\pi r}{T}$ (1) $T = 5800$ s (1) <u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $\therefore \omega = \sqrt{\frac{GM}{r^3}}$ $\therefore \omega = \sqrt{\frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6.0 \times 10^{24}\ \text{kg}}{(6.4 \times 10^6\ \text{m} + 5.5 \times 10^5\ \text{m})^3}} = 1.09 \times 10^{-3}\ \text{rad s}^{-1}$ $T = \frac{2\pi\ \text{rad}}{1.09 \times 10^{-3}\ \text{rad s}^{-1}} = 5755\ \text{s}$	3
16(b)	**Either** ($F = \frac{GMm}{r^2}$, so) the (gravitational) force is greater for a low Earth orbit (1) $F = m\left(\frac{2\pi}{T}\right)^2 r$ [accept angular velocity is greater] (1) So if F increases when r decreases, then T must decrease (1) (MP3 dependent upon MP1 **AND** MP2) **Or** ($\frac{2\pi}{T} = \sqrt{\frac{GM}{r^3}}$, so) $T^2 = \frac{4\pi^2 r^3}{GM}$ (1) G and M are constant, so $T \propto \sqrt{r^3}$ (1) So when r is smaller, T is smaller. (1) (MP3 dependent upon MP1 **OR** MP2) [Accept converse argument]	3

16(c)	Use of $V_{grav} = (-)\frac{GM}{r}$ (1) Use of $\Delta E_k = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ (1) $\Delta E_k = 1.1 \times 10^9$ J (1) [Do not credit use of $\Delta E_{grav} = mg\Delta h$, as g is not constant] Example of calculation $\Delta E_k = 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 6.0 \times 10^{24}\text{ kg} \times 227\text{ kg}\left(\frac{1}{6.4 \times 10^6\text{ m}} - \frac{1}{(6.4 \times 10^6 + 5.5 \times 10^5)\text{m}}\right)$ $\therefore \Delta E_k = 1.12 \times 10^9$ J		**3**
	Total for question 16		**9**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>17(a)</td><td>(The mass meets the conditions for simple harmonic motion as)

There is a (resultant) <u>force</u> acting on the mass which is proportional to its displacement from its equilibrium position.

The <u>force</u> is always directed towards the equilibrium position

(An equation with symbols defined, and the negative sign justified, may be a valid response for both marks

For equilibrium position accept: undisplaced point/position or fixed point/position or central point/position)</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>17(b)(i)</td><td>Use of $\Delta F = k\Delta x$

k =26.2 (N m^{-1})

<u>Example of calculation</u>

$k = \frac{0.2\text{ kg} \times 9.81\text{ N kg}^{-1}}{7.5 \times 10^{-2}\text{ m}} = 26.16\text{ N m}^{-1}$</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>17(b)(ii)</td><td>Combine $T = 2\pi\sqrt{\frac{m}{k}}$ with $f = \frac{1}{T}$ to obtain $f^2 = \frac{k}{4\pi^2}m^{-1}$

Compare with $y = mx + c$ to identify gradient as $\frac{k}{4\pi^2}$

Gradient of graph calculated

Large triangle used for gradient calculation

k =26.7 N m^{-1}

A conclusion consistent with the value calculated in (i)
(accept comparison with “show that” value from (i))

<u>Example of calculation</u>

$T^2 = \frac{4\pi^2 m}{k} \therefore f^2 = \frac{k}{4\pi^2}m$

So gradient $= \frac{k}{4\pi^2}$

Gradient= $\frac{(3.25 - 0.00)\text{ s}^{-2}}{(5.00 - 0.20)\text{ kg}^{-1}} = 0.677\text{ kg s}^{-2}$

$k = 4\pi^2 \times 0.677\text{ kg s}^{-2} = 26.7\text{ N m}^{-1}$</td><td>(1)

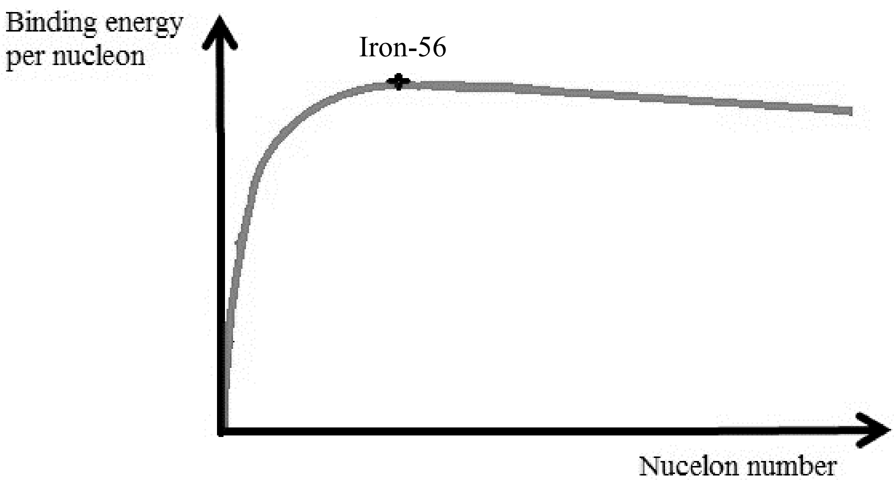
(1)

(1)

(1)

(1)

(1)</td><td>6</td></tr>
<tr><td></td><td>Total for question 17</td><td></td><td>10</td></tr>
</table>

Question Number	Answer	Mark
18(a)	A massive/large nucleus splits into smaller fragments (1)	**1**
18(b) (i)	Steeply rising curve near to origin (1) Slowly decreasing curve after peak (1)	**2**
18(b) (ii)	Iron-56 marked at peak of curve (1)	**1**
	Example of graph for (i) and (ii)  	
18(c)	Top line correct (1) Bottom line correct (1) $^{236}_{92}\text{U} \rightarrow {}^{93}_{38}\text{Sr} + {}^{141}_{54}\text{Xe} + 2 \times {}^{1}_{0}\text{n}$	**2**
18(d)	Calculation of mass defect (1) Binding energy per nucleon = 7.38 (MeV) (1) <u>Example of calculation</u> Mass defect = $(92\times0.93827+144\times0.93956-219.8750)\ \text{GeV}/c^2$ Mass defect $=1.74248\ \text{GeV}/c^2$ Binding energy/nucleon = 1.74248 GeV/236 = 7.383 MeV	**2**

***18(e)**

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.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

The following table shows how the marks should be awarded for structure and lines of reasoning.
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content

IC1 Energy from the α particles is transferred to atoms/molecules in the air

IC2 An electron in the atom/molecule is promoted to a higher energy state **Or** the atom/molecule/electron is excited

IC3 When the electron return to a lower energy state a photon (of uv-radiation) is emitted
Or when the atom/molecule/electron de-excites, a photon (of uv-radiation) is emitted

IC4 α radiation is strongly ionising and so has a short range (in air)

IC5 Ultraviolet radiation is weakly ionising (and has long range in air)

IC6 UV-radiation can be detected much further from the source so is safer

6

Total for question 18 14

Question Number	Answer		Mark
19(a)	Calculation of mass difference Conversion from u to kg, using a conversion factor of 1.66×10^{-27} kg u^{-1} Use of $\Delta E = c^2 \Delta m$ Conversion of energy to eV $\Delta E = 5.61$ (MeV) <u>Example of calculation</u> Mass difference = 237.999089 u – 233.991578 u – 4.001506 u = 6.005×10^{-3} u Mass difference = 6.005×10^{-3} u $\times 1.66 \times 10^{-27}$ kg = 9.9683×10^{-30} kg u^{-1} $\Delta E = c^2 \Delta m = (3.00 \times 10^8 \text{ m s}^{-1})^2 \times 9.9683 \times 10^{-30} \text{ kg} = 8.9715 \times 10^{-13}$ J $\Delta E = \dfrac{8.9715 \times 10^{-13}\text{ J}}{1.60 \times 10^{-13}\text{ J MeV}^{-1}} = 5.607$ MeV	(1) (1) (1) (1) (1)	**5**
19(b)	Convert α-particle energy from MeV to J Use of $\lambda = \dfrac{\ln 2}{t_{1/2}}$ Use of $A = A_0 e^{-\lambda t}$ Use of $P = \dfrac{\Delta E}{\Delta t}$ $P = 0.083$ (W) <u>Example of calculation</u> 5.6 MeV = $5.6 \times 1.60 \times 10^{-19}$ J MeV^{-1} = 8.96×10^{-13} J $\lambda = \dfrac{\ln 2}{t_{1/2}} = \dfrac{0.693}{87.7 \text{ year}} = 7.90 \times 10^{-3}$ year^{-1} $6.75 \times 10^{10} \text{ Bq} = A_0 \, e^{-7.90 \times 10^{-3} \text{ year}^{-1} \times 40 \text{ year}}$ $\therefore A_0 = 9.26 \times 10^{10}$ Bq *So* $P = 9.26 \times 10^{10} \text{s}^{-1} \times 8.96 \times 10^{-13} \text{ J} = 0.0830$ W	(1) (1) (1) (1) (1)	**5**

19(c)	Maximum energy of beta particles read from graph 1 (in range 210 keV → 225 keV) (1) Beta particle range read from graph 2 (in range 0.05 cm → 0.08 cm) **Or** max. energy for 0.5 cm polyethylene read from graph.2 (in range 1000 keV → 1200 keV) (1) Conclusion that 0.5 cm polyethylene would be sufficient (1) MP3 dependent on MP1 **and** MP2	3
	Total for question 19	**13**

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