# Mark Scheme (Results)

## Summer 2024

Pearson Edexcel Adanced Level GCE
In Physics (9PH0)
Paper 2: Advanced Physics II

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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 schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate.

**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 means of [no ue].

**3. Significant figures**

3.1 Use of too many significant figures in the theory questions will not be 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 m $s^{-2}$ or 10 N $kg^{-1}$ instead of 9.81 m $s^{-2}$ or 9.81 N $kg^{-1}$ will mean that one mark will not be awarded. (but not more than once per clip). Accept 9.8 m $s^{-2}$ or 9.8 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 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.

1. **Graphs**

1.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.

1.2 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.

1.3 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.

1.4 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** | The only correct answer is B<br>***A** is not correct because V, X and Z are all on the main sequence*<br>***C** is not correct because Z is on the main sequence and the sun will become a white dwarf, which is position Y*<br>***D** is not correct because Z, X and V are all on the main sequence* | **1** |
| **2** | The only correct answer is B<br>***A** is not correct because gravitational force is equal to centripetal force, so the velocity is independent of the mass of the satellite*<br>***C** is not correct because gravitational force is equal to centripetal force, so the velocity is independent of the mass of the satellite*<br>***D** is not correct because gravitational force is equal to centripetal force, so the velocity is independent of the mass of the satellite* | **1** |
| **3** | The only correct answer is C<br>***A** is not correct because the atomic mass number must decrease by 16, which corresponds to 4 alpha decays*<br>***B** is not correct because the atomic mass number must decrease by 16, which corresponds to 4 alpha decays*<br>***D** is not correct because the atomic number would decrease by 8 due to alpha decay, then increase by 6 due to beta decay* | **1** |
| **4** | The only correct answer is B<br>***A** is not correct because this produces a beam of electrons with a shorter de Broglie wavelength, which produces a smaller angle of diffraction*<br>***C** is not correct because increasing the filament temperature would have no effect on the wavelength of the electron beam*<br>***D** is not correct because diffraction is maximised when the wavelength is similar to the gap size, increasing the gap size would decrease the angle of diffraction* | **1** |
| **5** | The only correct answer is D<br>***A** is not correct because gravitational field strength is proportional to $1/r^2$*<br>***B** is not correct because electric field strength is proportional to $1/r^2$*<br>***C** is not correct because gravitational potential is always negative* | **1** |
| **6** | The only correct answer is C<br>***A** is not correct because smaller nuclei do not undergo fission*<br>***B** is not correct because larger nuclei do not undergo fusion*<br>***D** is not correct because larger nuclei do not undergo fusion* | **1** |
| **7** | The only correct answer is A<br>***B** is not correct because ray z has increased in speed, as shown by refracting away from the normal*<br>***C** is not correct because ray z has increased in speed, as shown by refracting away from the normal*<br>***D** is not correct because in medium y the ray has slowed down as it has refracted towards the normal* | **1** |

| | | |
|---|---|---|
| **8** | The only correct answer is D<br>***A*** *is not correct because elastic strain energy is equal to* $\frac{1}{2}F^2/k$<br>***B*** *is not correct because elastic strain energy is equal to* $\frac{1}{2}F^2/k$<br>***C*** *is not correct because elastic strain energy is equal to* $\frac{1}{2}F^2/k$ | **1** |
| **9** | The only correct answer is B<br>***A*** *is not correct because the initial gradient is not zero. The acceleration at the start is zero, so the velocity graph must have an initial gradient of zero*<br>***C*** *is not correct because the initial gradient is not zero*<br>***D*** *is not correct because the velocity in the first quarter cycle is decreasing* | **1** |
| **10** | The only correct answer is D<br>***A*** *is not correct because doubling the force and the length whilst halving the diameter leads to an increase by a factor of 16*<br>***B*** *is not correct because doubling the force and the length whilst halving the diameter leads to an increase by a factor of 16*<br>***C*** *is not correct because doubling the force and the length whilst halving the diameter leads to an increase by a factor of 16* | **1** |

**(Total for Multiple Choice Questions = 10 marks)**

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| **11** | • Use of $n\lambda = d \sin\theta$<br><br>• $\lambda = 5.33 \times 10^{-7}$ m | **(1)**<br><br>**(1)** | Example of calculation<br>$3\ \lambda = d \times 1.67 \times 10^{-6}$ m $\times \sin 73.3°$<br>$\lambda = 5.33 \times 10^{-7}$ m | **2** |

**Total for Question 11 = 2 marks**

| Question Number | Acceptable answers | Additional guidance | Mark |
|---|---|---|---|
| **12(a)(i)** | • The (minimum) frequency at/above which electrons are released **(1)** | Accept frequency below which electrons are not released | **1** |
| **12(a)(ii)** | An explanation that makes reference to the following points:<br>• With waves, energy would build up **(1)**<br>• A photoelectron would (eventually have enough energy to) be emitted with any frequency, (which is not observed) **(1)** | | **2** |
| **12(b)** | • A <u>quantum</u> of (electromagnetic) energy/radiation<br>**Or**<br>A <u>discrete</u> packet of (electromagnetic) energy/radiation **(1)** | Accept light for energy/radiation | **1** |

**(Total for Question 12 = 4 marks)**

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| **13** | • Use of $\lambda_{max}\ T = 2.898 \times 10^{-3}$ m K | **(1)** | Example of calculation<br>$7.43 \times 10^{-7}$ m $\times\ T = 2.898 \times 10^{-3}$ m K<br>$T = 3900$ K | **4** |
| | • Use of $A = 4\pi r^2$ | **(1)** | $A = 4\pi\ (3.14 \times 10^{10}\ \text{m})^2$<br>$= 1.24 \times 10^{22}\ \text{m}^2$ | |
| | • Use of $L = \sigma A T^4$ | **(1)** | $L = 5.67 \times 10^{-8}$ W m$^{-2}$ K$^{-4} \times 1.24 \times 10^{22}$ m$^2 \times (3900$ K$)^4$ | |
| | • $L = 1.63 \times 10^{29}$ W | **(1)** | $L = 1.63 \times 10^{29}$ W | |

**(Total for Question 13 = 4 marks)**

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| **14(a)** | • Use of $1/f = P$<br>• Use of $P = P_1 + P_2$<br>• $P = 17$ (D) | **(1)**<br>**(1)**<br>**(1)** | Example of calculation<br>$P_1 = 1/0.1$ m = 10 D<br>$P_2 = 0.15$ m = 6.7 D<br>$P = 10$ D + 6.7 D<br>= 16.7 D<br><br>$P = 1/0.1$ m + $1/0.15$ m for MP1 **and** MP2 | **3** |
| **14(b)** | • Use of $1/v + 1/u = 1/f$ **Or** $1/v + 1/u = P$<br>• $v = (-)$ 12 cm (ecf from a) | **(1)**<br>**(1)** | Example of calculation<br>$1/v + 1/(0.04$ m) = 16.7 D<br>$v = -0.12$ m<br><br>(Show that answer gives 20 cm) | **2** |
| **14(c)** | • Use of $M = v/u$<br>• Use of $M$ = (image height) / (object height)<br>• Image height = 4.2 cm (ecf from b) | **(1)**<br>**(1)**<br>**(1)** | Example of calculation<br>$M = 12$ cm / 4 cm = 3<br>$I = 3 \times 1.4$ cm = 4.2 cm<br><br>(Show that from (a) gives 7.0 cm) | **3** |
| **14(d)** | • Virtual **and** erect/upright | **(1)** | | **1** |

**(Total for Question 14 = 9 marks)**

| Question Number | Acceptable answers | Additional guidance | Mark |
|---|---|---|---|
| 15(a) | **EITHER**<br>• Waves are produced by the toothbrush and reflected (at the mass) **(1)**<br>• Waves meet and superpose **(1)**<br>• Constructive interference takes place where the waves are in phase<br>**Or**<br>Destructive interference takes place where the waves are in antiphase **(1)**<br>• The string vibrates at the centre with maximum amplitude, forming an antinode in the centre<br>**Or**<br>The string here has zero/minimum amplitude, forming nodes at the ends **(1)**<br>• Creating a standing/stationary wave **(1)**<br>**OR**<br>• The toothbrush causes the string to vibrate at its natural frequency **(1)**<br>• There is a maximum/efficient transfer of energy from the toothbrush to the string **(1)**<br>• Resonance occurs **(1)**<br>• The string vibrates at the centre with maximum amplitude, forming an antinode in the centre **(1)**<br>• Creating a standing/stationary wave **(1)** | Accept answer in terms of multiple 'loops'<br><br>Accept reference to phase difference in terms of $2\pi$, or 0 (radians)<br><br>Accept reference to phase difference in terms of $\pi$ (radians)<br>Do not credit out of phase | **5** |

| | | | |
|---|---|---|---|
| **15(b)** | • Use of $W = mg$ **(1)**<br>• Use of $v = \sqrt{(T/\mu)}$ **(1)**<br>• Determination of wavelength **(1)**<br>• Use of $v = f\lambda$ **(1)**<br>• $f$ = 30 Hz **(1)** | Example of calculation<br>$T = 0.010\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 0.0981\ \text{N}$<br>$v = \sqrt{(0.0981\ \text{N} / 9.1 \times 10^{-4}\ \text{kg m}^{-1})} = 10.4\ \text{m s}^{-1}$<br>$\lambda = 0.69\ \text{m} / 2 = 0.345\ \text{m}$<br>$f = 10.4\ \text{m s}^{-1} / 0.345\ \text{m}$<br>$= 30\ \text{Hz}$ | **5** |

**(Total for Question 15 = 10 marks)**

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| **16(a)** | • Use of $f = 1 / T$ | **(1)** | Example of calculation<br>$T = 1 / 0.34$ Hz = 2.94 s<br>2.94 s = $2\pi \sqrt{(m/350\ \text{N m}^{-1})}$<br>$m$ = 76.6 kg<br>mass of astronaut = 76.6 kg – 5.7 kg<br>= 70.9 kg | **4** |
| | • Use of $T = 2\pi \sqrt{(m/k)}$ | **(1)** | | |
| | • Correct for mass of platform | **(1)** | | |
| | • Mass of astronaut = 71 kg | **(1)** | | |
| **16(b)(i)** | • Determine amplitude | **(1)** | Example of calculation<br>Amplitude = 0.29 m / 2 = 0.145 m<br>$\omega = 2\pi \times 0.34$ Hz = 2.14 rad $s^{-1}$<br>max $a = (2.14\ \text{rad s}^{-1})^2 \times 0.145$ m<br>= 0.66 m $s^{-2}$ | **4** |
| | • Use of $\omega = 2\pi f$ | **(1)** | | |
| | • Use of max $a = (–)\ \omega^2 A$ | **(1)** | | |
| | • Max acceleration = 0.66 m $s^{-2}$ | **(1)** | | |
| **16(b)(ii)** | • Use of $v = (–)\ A\omega \sin \omega t$ | **(1)** | Example of calculation<br>$v = 0.145 \times 2.14\ \text{s}^{-1} \sin((2.14\ \text{s}^{-1} \times 3.5\ \text{s})\ \text{radian})$<br>$= 0.145 \times 2.14\ \text{s}^{-1} \sin((2.14\ \text{s}^{-1} \times 3.5\ \text{s}) \times 360° / 2\pi)$<br>Speed = 0.29 m $s^{-1}$ | **2** |
| | • Speed = 0.29 m $s^{-1}$ (ecf for $\omega$ and A from (b)(i)) | **(1)** | | |

**(Total for Question 16 = 10 marks)**

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| **17(a)** | • Use of $pV = NkT$ | **(1)** | Example of calculation<br>$p_1 V_1 = NkT_1$<br>$p_1 V_1 / T_1 = NkT_1 = p_2 V_2 / T_2$<br>$V_1$ / 293 K = 2800 m$^3$ / 393 K<br>Volume of gas before heating, $V_1$ = 2087 m$^3$<br>mass of air in balloon<br>= 1.2 kg m$^{-3}$ × 2087 m$^3$<br>= 2505 kg<br>Total mass with 5 passengers<br>= (2505 + 340 + 380) kg = 3225 kg<br>$W$ = 3225 kg × 9.81 N kg$^{-1}$ = 31 637 N<br>31 600 N < 33 000 N | **6** |
| | • Conversion of $T$ in K | **(1)** | | |
| | • Use of $\rho = m/V$ to determine mass of air in the balloon | **(1)** | | |
| | • Calculation of total mass = mass of air at 120 °C + passengers + balloon | **(1)** | | |
| | • Use of $W = mg$ | **(1)** | | |
| | • $W$ = 31 600 N, which is less than 33 000 N, so the balloon can take off | **(1)** | | |
| **17(b)(i)** | Any one from:<br>• Point particles<br>• Particles have negligible volume (compared to their container)<br>• Negligible forces between particles (except during a collision)<br>• Range of molecular forces small (in comparison to average separation)<br>• Duration of collisions negligible (in comparison to time between them)<br>• Newtonian mechanics applies<br>• Particles moves with uniform velocity between collisions<br>• Elastic collisions<br>• Particles move with (constant) random motion | **(1)** | Accept molecules for particles | **1** |

| | | | |
|---|---|---|---|
| **17(b)(ii)** | • States $pV = NkT$ or $pV = 1/3\ Nm\langle c^2\rangle$ **(1)**<br>• Suitable algebra to show $\frac{1}{2}\ m\langle c^2\rangle = 3/2\ kT$ **(1)** | | **2** |
| **17(b)(iii)** | • Use of a.m.u. to determine particle mass **(1)**<br>• Use of $\frac{1}{2}\ m\langle c^2\rangle = 3/2\ kT$ with T in K **(1)**<br>• rms speed = 590 m $s^{-1}$ **(1)** | Example of calculation<br>Mass = $28 \times 1.66 \times 10^{-27}$ kg = $4.65 \times 10^{-26}$ kg<br>$\frac{1}{2} \times 4.65 \times 10^{-26}$ kg $\langle c^2\rangle = 3/2 \times 1.38 \times 10^{-23}$ J $K^{-1} \times 393$ K<br>$c = \sqrt{349900} = 590$ m $s^{-1}$ | **3** |

**(Total for Question 17 = 12 marks)**

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*18(a)</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.<br><br>
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>
The following table shows how the marks should be awarded for indicative content.<br><br>
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th><th>Max linkage mark available</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>
</td><td>
The following table shows how the marks should be awarded
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></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>
for structure and lines of reasoning.<br><br>
Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).
</td><td></td></tr>
</table>

| | | | |
|---|---|---|---|
| | **Indicative content:**<br><br>IC1 Electrons are in (discrete) energy levels<br><br>IC2 Absorption of (a single) photon causes an electron to move to a higher energy level<br><br>IC3 Photon energy = $hf$<br>**Or** photon energy is proportional to frequency<br><br>IC4 Energy of (absorbed) photon must equal difference in energy levels<br><br>IC5 The (changes in) energy levels are specific to each element<br><br>IC6 Different wavelengths/frequencies of light are absorbed | | **6** |
| **18(b)** | • Use of $c = f\lambda$ **(1)**<br><br>• Use of $\Delta E = hf$ **(1)**<br><br>• Use of 1 eV = 1.6 x $10^{-19}$ J **(1)**<br><br>• Change in energy equal to 1.89 eV and transition from energy level 2 to energy level 3 **(1)** | <u>Example of calculation</u><br>$f =$ 3.00 × $10^{8}$ m $s^{-1}$ / 656.46 ×$10^{-9}$ m<br>= 4.57 × $10^{14}$ Hz<br>$E$ = 6.63 × $10^{-34}$ J s × 4.57 × $10^{14}$ Hz<br>= 3.03 × $10^{-19}$ J<br>= 3.03 × $10^{-19}$ J / 1.60 × $10^{-19}$ = 1.89 eV<br>1.89 eV – 3.40 eV = – 1.51 eV = level 3 | **4** |

| | | | |
|---|---|---|---|
| **18(c)(i)** | • (According to the Doppler effect) if the source is moving away from the observer the wavelength will increase **(1)**<br>• (According to the Doppler effect) there is a change in wavelength proportional to velocity **(1)**<br>• He is correct (as speed and direction can be determined). **(1)**<br>MP3 dependent on MP1 and MP2 | Allow converse statement i.e. If the source is moving towards the observer the wavelength will decrease | **3** |
| **18(c)(ii)** | • Use of $\Delta\lambda / \lambda_0 = v/c$ **(1)**<br>• $\lambda = 656 \times 10^{-9}$ m **(1)** | Must see $656.46 \times 10^{-9}$ m in denominator<br><br>Example of calculation<br>$\Delta\lambda = 656.46 \times 10^{-9}$ m $\times 5.5 \times 10^{3}$ m s$^{-1}$/$3.00 \times 10^{8}$ m s$^{-1}$<br>$= 0.012 \times 10^{-9}$ m<br>Moving away, so add $\Delta\lambda$<br>$\lambda = 656.46 \times 10^{-9}$ m + $0.012 \times 10^{-9}$ m<br>$\lambda = 656.47 \times 10^{-9}$ m | **2** |

**(Total for Question 18 = 15 marks)**

| Question Number | Acceptable answers | Additional guidance | Mark |
|---|---|---|---|
| **19(a)(i)** | • (Spontaneous) – independent of external conditions **(1)**<br>• (Random) – cannot predict when a decay will occur **(1)** | Accept cannot tell which nucleus will decay next | **2** |
| **19(a)(ii)** | • The probability of decay (in a specified time) may be determined **(1)**<br>• (Probability may be applied accurately because) very large numbers are involved **(1)** | For MP1 accept reference to the proportion of nuclei decaying at a specified time | **2** |
| **19(b)** | A description that makes reference to the following points:<br>• Measure the background count (rate) **(1)**<br>• Measure count (rate) from source **(1)**<br>• Use paper to absorb alpha radiation **(1)**<br>• Percentage $= \frac{\text{count with paper}(-\text{background rate})}{\text{count from source }(-\text{background rate})} \times 100$ **(1)** | | **4** |
| **19(c)(i)** | • Use of $\ln 2 = \lambda t_{1/2}$ **(1)**<br>• Use of $A = A_0 e^{-\lambda t}$ **(1)**<br>• Expected percentage of $A_0$ = 95 % **(1)** | <u>Example of calculation</u><br>$\lambda = \ln 2 / 432$ years $= 1.6 \times 10^{-3}$ y$^{-1}$<br>$A / A_0 = e^{-(1.6 \times 10-3 \text{ y}-1 \times 34 \text{ y})}$<br>$(A / A_0) \times 100$ % = 94.7 % | **3** |

| | | | |
|---|---|---|---|
| **19(c)(ii)** | • Beta is only emitted after the decay of neptunium to protactinium **(1)**<br>**Or**<br>Americium and neptunium only emit alpha **(1)**<br><br>• The half-life of <u>neptunium</u> is very long **(1)**<br><br>• There will only be a very small proportion of protactinium (relative to americium and neptunium), so the suggestion is incorrect<br>**Or**<br>Only 5% of the americium has decayed so the proportion of protactinium is very small, so the suggestion is incorrect | Accept amount for proportion | **3** |

**(Total for Question 19 = 14 marks)**
**TOAL FOR PAPER = 90 MARKS**

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