Mark Scheme (Results)

Summer 2026

Pearson Edexcel International Advanced Level In Physics
WPH15/01

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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 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}

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.

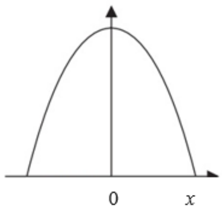
4.3 The mark scheme will show a correctly worked answer for illustration only.

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 (The total mass of the nuclei decreases.)** A is not correct because this is a condition for fusion B is not correct because this is a condition for fusion C is not correct because binding energy does not stay constant	1
2	**The only correct answer is D (It is possible to predict which nucleus will decay next.)** A is not correct because this is a correct feature of radioactive decay B is not correct because this is a correct feature of radioactive decay C is not correct because this is a correct feature of radioactive decay	1
3	**The only correct answer is C** $(\mathbf{[mass\ of\ X - mass\ of\ Y - mass\ of\ \alpha] \times c^2})$ A is not correct because the energy released is the mass difference multiplied by c^2 B is not correct because the energy released is the mass difference multiplied by c^2 D is not correct because the energy released is the mass difference multiplied by c^2	1
4	**The only correct answer is C (Y Z X)** A is not correct because galaxy X is further away than galaxy Y B is not correct because galaxy X is further away than galaxy Z D is not correct because galaxy Z is further away than galaxy Y	1
5	**The only correct answer is B**  **B** A is not correct because the KE cannot be zero at the equilibrium position C is not correct because the KE is not a maximum at the amplitude D is not correct because the KE does not stay constant	1
6	**The only correct answer is D** $\left(\frac{6.67\times10^{-11}\times1.3\times10^{25}\times750}{(7.9\times10^{6})^2}\right)$ A is not correct because $F = \frac{GMm}{r^2}$ B is not correct because $F = \frac{GMm}{r^2}$ C is not correct because $F = \frac{GMm}{r^2}$	1
7	**The only correct answer is D (** The field strength for each field is proportional to $\left(\frac{1}{\text{distance from proton}}\right)$) A is not correct because this is a correct statement B is not correct because this is a correct statement C is not correct because this is a correct statement	1

8	**The only correct answer is D** $\left(-GM_E \times \left(\frac{1200}{R_E+2000} - \frac{1200}{R_E}\right)\right)$ A is not correct because $\Delta E = \frac{GMm}{r_{\text{final}}} - \frac{GMm}{r_{initial}}$ B is not correct because $\Delta E = \frac{GMm}{r_{\text{final}}} - \frac{GMm}{r_{initial}}$ C is not correct because $\Delta E = \frac{GMm}{r_{\text{final}}} - \frac{GMm}{r_{initial}}$	**1**
9	**The only correct answer is C (The heater was switched on for a time greater than *t*.)** A is not correct because this would increase the value for the specific latent heat B is not correct because this would increase the value for the specific latent heat D is not correct because this would increase the value for the specific latent heat	**1**
10	**The only correct answer is B** $(\mathbf{2.5 \times 10^3}\ L_\odot)$ A is not correct because $L = \sigma A T^4$ and $A = 4\pi r^2$ C is not correct because $L = \sigma A T^4$ and $A = 4\pi r^2$ D is not correct because $L = \sigma A T^4$ and $A = 4\pi r^2$	**1**

Question Number	Acceptable Answer		Additional Guidance	Mark
11	Use of $pV = NkT$ Conversion of temperature to kelvin $p = 2.4 \times 10^7$ Pa	(1) (1) (1)	Example of calculation $\frac{p_2}{T_2} = \frac{p_1}{T_1}$ $\therefore p_2 = \frac{2.33 \times 10^7 \text{Pa} \times (32 + 273)\text{K}}{(18 + 273)\text{K}} = 2.44 \times 10^7 \text{ Pa}$	3

(Total for Question 11 = 3 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
12(a)	Use of $E = mc\Delta\theta$ **(1)** Calculation of mass of liquid that flows in each second **(1)** Rate of transfer of energy $= 3.7 \times 10^4$ W **(1)**	<u>Example of calculation</u> Flow rate $= \frac{75\ \text{kg}}{60\ \text{s}} = 1.25\ \text{kg s}^{-1}$ $P = 1.25\ \text{kg s}^{-1} \times 2.3 \times 10^3\ \text{J kg}^{-1}\ \text{K}^{-1}(98 - 85)\ \text{K}$ $P = 3.74 \times 10^4\ \text{W}$	3
12(b)	Water has a larger value of specific heat capacity **(1)** Rate of which energy transfer away from engine stays constant **(1)** So the change in temperature would be less (dependent on MP1) **(1)**		3

(Total for Question 12 = 6 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
13(a)	Internal energy is sum of molecular kinetic energies Substitutes from $pV = NkT$ with algebra to obtain $U = \frac{3}{2}pV$	(1) (1)	Allow $U = N \times \frac{3}{2}kT$ **Or** $U = N \times \frac{1}{2}m\langle c^2\rangle$ **Do not credit substituting $N = 1$** <u>Example of derivation</u> $U = N \times \frac{1}{2}m\langle c^2\rangle$ $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$, so $U = N \times \frac{3}{2}kT$ $pV = NkT$ so $U = \frac{3}{2}pV$	2
13(b)	Use of $U = \frac{3}{2}pV$ Use of $U = \frac{1}{2}m\langle c^2\rangle \times N$ Average kinetic energy of molecules = 6.4×10^{-21} J	(1) (1) (1)	Use of $pV = NkT$ Use of $E_k = \frac{3}{2}kT$ <u>Example of calculation</u> $U = \frac{3}{2}pV = \frac{3}{2} \times 1.4 \times 10^5 \text{ Pa} \times 2.6 \times 10^{-3} \text{ m}^3 = 546 \text{ J}$ $546 \text{ J} = 8.5 \times 10^{22} \times \frac{1}{2}m\langle c^2\rangle$ $\therefore \frac{1}{2}m\langle c^2\rangle = \frac{546 \text{ J}}{8.5 \times 10^{22}} = 6.42 \times 10^{-21} \text{ J}$	3

(Total for Question 13 = 5 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
14	Use of $\rho = \frac{m}{V}$	**(1)**		
	Use of 32 %	**(1)**		
	Use of $\Delta E = mL$	**(1)**		
	Energy required $= 8.7 \times 10^4$ J	**(1)**		**4**
			Example of calculation $m = \rho V = 550 \text{ kg m}^{-3} \times 1.50 \times 10^{-3} \text{ m}^3 = 0.825 \text{ kg}$ Mass of ice $= 0.32 \times 0.825 \text{ kg} = 0.264 \text{ kg}$ $\Delta E = 0.264 \times 3.30 \times 10^5 \text{J kg}^{-1} = 8.71 \times 10^4 \text{ J}$	

(Total for Question 14 = 4 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
15	Use of $\frac{\Delta f}{f} = \frac{v}{c}$ **(1)** $v = 36\ \text{m s}^{-1}$ **(1)** Use of 10% with $31\ \text{m s}^{-1}$ Or Calculation of excess speed % **(1)** $36\ (\text{m s}^{-1}) > 34.1\ (\text{m s}^{-1})$ so speed limit is exceeded **Or** Recorded speed is 16% more than limit so speed limit exceeded **Or** Comparison of calculated value of speed with maximum permitted speed with conclusion. **(1)**	Allow comparison with $31\ \text{m s}^{-1}$ <u>Example of calculation</u> $\frac{2880\ \text{Hz}}{2.41 \times 10^{10}\ \text{Hz}} = \frac{v}{3.00 \times 10^{8}\ \text{m s}^{-1}}$ $\therefore v = 35.9\ \text{m s}^{-1}$ Maximum permitted speed $= 31\ \text{m s}^{-1} \times 1.1 = 34.1\ \text{m s}^{-1}$ $35.9\ \text{m s}^{-1} > 34.1\ \text{m s}^{-1}$ so speed limit is exceeded Excess speed % $= \frac{35.9 - 31}{31} \times 100\% = 15.8\%$ 16% > 10%, so speed limit is exceeded	4

(Total for Question 15 = 4 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>16(a)</td><td>Reverse scale (1)

Logarithmic scale (1)</td><td>Any reverse scale will do

There must be at least 2 temperatures added to the axis</td><td>2</td></tr>
<tr><td>*16(b)</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning.

<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>

Indicative content
IC1 Star fuses hydrogen in core of the star at position A
IC2 When hydrogen (in core) is used up (rate of) fusion decreases/ceases
IC3 The core collapses / contracts (under gravitational forces)
IC4 Temperature rises and helium fusion starts
Or Temperature is high enough for helium fusion
IC5 The Sun expands into a red giant, at position B
IC6 When no further fusion takes place, core/star collapses (into a white dwarf), at position C</td>
<td>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>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage 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 linkage between points and is unstructured</td><td>0</td></tr>
</table>

IC4: Must be temperature rise to start helium fusion not temperature rises after helium fusion starts.</td><td>6</td></tr>
</table>

(Total for Question 16 = 8 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
17(a)	**EITHER** Use of right angle trigonometry $\theta = 5.36 \times 10^{-9}$ rad 5.36×10^{-9} (rad) $>$ 4.75×10^{-9} (rad) so distance can be determined **Or** calculated value of θ compared with 4.75×10^{-9} (rad) with consistent conclusion **OR** Use of right angle trigonometry $x = 3.2 \times 10^{19}$ m 2.8×10^{19} (m) $<$ 3.2×10^{19} (m) so distance can be determined. **Or** calculated value of x compared with 2.8×10^{19} m with consistent conclusion.	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	Allow use of small angle approximation. Allow use of sin θ or tan θ Example of calculation $\tan(\theta) = \dfrac{1.50 \times 10^{11}\text{ m}}{2.8 \times 10^{19}\text{ m}} = 5.36 \times 10^{-9}$ rad 5.36×10^{-9} rad $>$ 4.75×10^{-9} (rad) so distance can be determined. $\tan(4.75 \times 10^{-9}\text{ rad}) = \dfrac{1.50 \times 10^{11}\text{ m}}{x}$ $x = \dfrac{1.50 \times 10^{11}\text{ m}}{4.75 \times 10^{-9}} = 3.16 \times 10^{19}$ m 2.8×10^{19} m $<$ 3.2×10^{19} m so distance can be determined.	3
17(b)	Determine the red shift **Or** determine $\frac{\Delta\lambda}{\lambda}$ Calculate the (recessional) velocity Use Hubble's law to calculate distance	**(1)** **(1)** **(1)**	Allow speed for velocity Allow reference to $v = H_0 d$ for Hubble's law [e.g. $d = v \times \frac{1}{H_0}$]	3

(Total for Question 17 = 6 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
18(a)	**EITHER** use of $A = \lambda N$ **(1)** Use of 1 u = 1.66×10^{-27} kg **(1)** Calculation of percentage of uranium **(1)** Percentage of uranium in sample is 63% **(1)** Calculated % compared with 65%, with consistent conclusion **(1)** **OR** Use of 65% to calculate mass **(1)** Use of 1 u = 1.66×10^{-27} kg **(1)** use of $A = \lambda N$ **(1)** Activity of typical sample = 2.23×10^4 Bq **(1)** Calculated activity compared with 2.15×10^4 Bq, with consistent conclusion **(1)** **OR** Use of $A = \lambda N$ **(1)** Use of 1 u = 1.66×10^{-27} kg **(1)** Use of 65% to calculate mass **(1)** Mass of sample = 1.73×10^{-3} kg **Or** mass of 65% of sample = 1.79×10^{-3} kg **(1)** Calculated mass compared with 1.79×10^{-3} kg, with consistent conclusion **(1)** **OR** Use of $A = \lambda N$ Use of 1 u = 1.66×10^{-27} kg **(1)** Use of 65% to calculate number of nuclei in sample **(1)** $N = 4.37 \times 10^{21}$ **(1)** **Or** $N = 4.52 \times 10^{21}$ **(1)** $N = 4.37 \times 10^{21} \approx 4.52 \times 10^{21}$ so in agreement with a typical sample **(1)**	<u>Example of calculation</u> $2.15 \times 10^4 \text{ Bq} = 4.92 \times 10^{-18} \text{ s}^{-1} N$ $N = 4.37 \times 10^{21}$ mass of uranium atom = $238 \times 1.66 \times 10^{-27}$ kg = 3.95×10^{-25} kg mass of uranium = $4.37 \times 10^{21} \times 3.95 \times 10^{25}$ kg = 1.73×10^{-3} kg % uranium in sample = $\frac{1.73 \text{ g}}{2.75 \text{ g}} \times 100\% = 62.8\%$ 63% ≈ 65%, so activity is in agreement with typical sample Mass = $0.65 \times 2.75 \times 10^{-3}\text{kg} = 1.79 \times 10^{-3}\text{kg}$ $N = \frac{1.79 \times 10^{-3}\text{kg}}{238 \times 1.66 \times 10^{-27} \text{ kg}} = 4.52 \times 10^{21}$ $A = 4.92 \times 10^{-18}\text{s}^{-1} \times 4.52 \times 10^{21} = 2.23 \times 10^4\text{Bq}$ $2.23 \times 10^4\text{Bq} \approx 2.15 \times 10^4\text{Bq}$ so activity is in agreement with a typical sample **For each conclusion allow X > Y, so not consistent as well as X ≈ Y, so consistent.**	5

18(b)	Alpha particles have a (very) short range **Or** alpha particles are absorbed by the skin **Or** alpha particles do not penetrate the skin **(1)** Alphas are only a danger if taken into the body **(1)**	Accept alphas have a low penetration Accept alphas may not escape from the sample/torbernite Accept alphas will not be able to enter the body **Or** alpha can ionise cells in the body	**2**

(Total for Question 18 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
19(a)	(Very) high temperature **(1)** So that nuclei/protons have enough kinetic energy to come close enough to fuse **(1)** (Very) high density/pressure **(1)** So that rate of collision is high enough to maintain/sustain fusion **(1)**	So that nuclei/protons have enough kinetic energy to come close enough to overcome the electrostatic force/repulsion (between nuclei) Not 'particles', not 'molecules', not 'atoms' Allow 'frequency of collision', 'collide more often' for rate of collision [reject number of collisions]	**4**
19(b)(i)	Top line correct **(1)** Bottom line correct **(1)**	Example of equation $^{3}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{0}_{-1}\beta + {}^{0}_{0}\overline{\nu}_e$	**2**

19(b)(ii)	**EITHER** Use of $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ Use of $A = \lambda N$ Use of $A = A_0 e^{-\lambda t}$ **Or** Use of $N = N_0 e^{-\lambda t}$ $A = 3.0 \times 10^8$ Bq 3.00×10^8 (Bq) $>$ 2.78×10^8 (Bq), so the manufacturer's claim is correct. **Or** calculated value of A compared with 2.78×10^8 Bq with consistent conclusion. **OR** Use of $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ Use of $A = \lambda N$ Use of $A = A_0 e^{-\lambda t}$ **Or** Use of $N = N_0 e^{-\lambda t}$ $t = 6.72 \times 10^8$ s [= 21.3 year] 21.3 (years) $>$ 20 (years), so the manufacturer's claim is correct. **Or** calculated value of t compared with 20 (years) with consistent conclusion.	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	Example of calculation $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{0.693}{(12.3\ \times 3.15 \times 10^7)\text{ s}} = 1.79 \times 10^{-9}\text{ s}^{-1}$ $A = \lambda N = 1.79 \times 10^{-9}\text{ s}^{-1} \times 5.17 \times 10^{17} = 9.26 \times 10^8$ Bq $A = 9.26 \times 10^8\text{ Bq} \times e^{-1.79\times10^{-9}\text{ s}^{-1}\times(20\times3.15\times10^7)\text{ s}}$ $A = 9.26 \times 10^8\text{ Bq} \times 0.324 = 2.998 \times 10^8$ Bq $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{0.693}{(12.3\ \times 3.15 \times 10^7)\text{ s}} = 1.79 \times 10^{-9}\text{ s}^{-1}$ $A = \lambda N = 1.79 \times 10^{-9}\text{ s}^{-1} \times 5.17 \times 10^{17} = 9.26 \times 10^8$ Bq $2.78 \times 10^8 Bq = 9.26 \times 10^8\text{ Bq} \times e^{-1.79\times10^{-9}\text{ s}^{-1}t}$ $t = \frac{\ln\left(\frac{2.78 \times 10^8\text{ Bq}}{9.26 \times 10^8\text{ Bq}}\right)}{1.79 \times 10^{-9}\text{ s}^{-1}} = 6.72 \times 10^8$ s $t = \frac{6.72 \times 10^8\text{ s}}{3.15 \times 10^7\text{ s year}^{-1}} = 21.3$ years **20 years = 6.3×10^8 s**	**5**

(Total for Question 19 = 11 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
20(a)	There is a (resultant) acceleration / force that is proportional to the displacement from the equilibrium point/position and (always) acting towards the equilibrium point/position	**(1)** **(1)**	Reject 'equilibrium', but allow **1 MAX** if point/position omitted in both MP. For equilibrium position accept: undisplaced/fixed/central point/position Allow 'in the opposite direction (to displacement)' Accept an equation with symbols defined correctly for both marks	**2**
20(b)(i)	Use of $W = mg$ **and** $\Delta F = k\Delta x$ $k = 6.1 \times 10^4$ (N m^{-1}) (at least 2 sf)	**(1)** **(1)**	Example of calculation $k = \frac{75\ \mathrm{kg} \times 9.81\ \mathrm{N\ kg^{-1}}}{1.2 \times 10^{-2}\mathrm{m}} = 6.13 \times 10^4\ \mathrm{N\ m^{-1}}$	**2**
20(b)(ii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ Use of $f = \frac{1}{T}$ Frequency = 1.8 Hz (ecf from b(i))	**(1)** **(1)** **(1)**	Allow $\omega^2 = \frac{k}{m}$ with $\omega = 2\pi f$ for MP1 and MP2 Example of calculation $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{(350 + 125)\mathrm{kg}}{6.1 \times 10^4\ \mathrm{N\ m^{-1}}}} = 0.554\ \mathrm{s}$ $f = \frac{1}{0.554\ \mathrm{s}} = 1.80$ Hz [show that value gives 1.79 Hz]	**3**
20(c)(i)	Resonance occurs When the driving frequency matches the natural frequency (of the carriage) There is a maximum transfer of energy to the carriage (and the amplitude of oscillation has a maximum value)	**(1)** **(1)** **(1)**	Ignore references to donkey For 'driving frequency' accept forcing frequency, or idea frequency of carriage meeting bumps Accept efficient transfer of energy	**3**
20(c)(ii)	Damping could be added (to the carriage springs) Energy would be transferred away from the carriage **Or** energy would be transferred to the surroundings **Or** thermal energy store (of dampers) would increase (Because) work would be done against resistive forces	**(1)** **(1)** **(1)**	Allow a reference to adding a shock absorber Allow energy would be dissipated Allow 'oscillating system' for 'carriage' Ignore any references to plastic deformation.	**3**

(Total for Question 20 = 13 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
21(a)(i)	Gravitational force equated to centripetal force **(1)** Use of $T = \frac{2\pi}{\omega}$ **(1)** Orbital time = 226 (days) **(1)**	Allow in terms of ω or v Allow use of $v = \frac{2\pi r}{T}$ <u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $T^2 = \frac{4\pi^2 r^3}{GM}$ $\frac{T_{Venus}^2}{T_{Earth}^2} = \frac{r_{Venus}^3}{r_{Earth}^3}$ $T_{Venus} = \sqrt{\frac{(365\ \text{days})^2 \times (1.09 \times 10^{11}\text{m})^3}{(1.50 \times 10^{11}\text{m})^3}} = 226\ \text{days}$	**3**
21(a)(ii)	**EITHER** (Smaller mass would mean a) smaller gravitational force (at a given position) **(1)** Centripetal force decreases so r increases **(1)** **OR** (Smaller mass would mean a) smaller gravitational field strength (at a given position) **(1)** Centripetal acceleration decreases so r increases **(1)**	. Accept $\frac{mv^2}{r}$ for centripetal force Accept $\frac{v^2}{r}$ for centripetal acceleration **Ignore references to gravitational potential for MP1**	**2**

21(b)(i)	λ_{max} read from graph **(1)** Use of $\lambda_{\text{max}}T = 2.898 \times 10^{-3}$ m K **(1)** $T = 5800$ (K) (at least 2sf) **(1)**	Accept a reasonable attempt to read λ_{max} from graph <u>Example of calculation</u> $\lambda_{\text{max}} = 500$ nm $T = \frac{2.898 \times 10^{-3} \text{ m K}}{500 \times 10^{-9} \text{ m}} = 5796$ K	**3**
21(b)(ii)	Use of 25% to calculate intensity at top of atmosphere **(1)** Use of $I = \frac{L}{4\pi d^2}$ **(1)** Use of $A = 4\pi r^2$ **(1)** Use of $L = \sigma A T^4$ **(1)** $r = 6.9 \times 10^8$ m [ecf from (i)] [Show that value gives 6.4×10^8 m] **(1)**	<u>Example of calculation</u> At top of atmosphere $I = 4 \times 340 \text{ W m}^{-2} = 1360 \text{ W m}^{-2}$ $L = 1360 \text{ W m}^{-2} \times 4\pi \times (1.49 \times 10^{11} \text{ m})^2$ $\therefore L = 3.79 \times 10^{26}$ W $A = \frac{3.79 \times 10^{26} \text{ W}}{5.67 \times 10^{-8} \text{W m}^{-2} \text{ K}^{-4} \times (5800 \text{ K})^4} = 5.91 \times 10^{18} \text{ m}^2$ $r = \sqrt{\frac{5.91 \times 10^{18} \text{ m}^2}{4\pi}} = 6.86 \times 10^8$ m	**5**

(Total for Question 21 = 13 marks)
TOTAL FOR PAPER = 90 MARKS