Pearson Edexcel

Mark Scheme (Results)

Summer 2025

Pearson Edexcel International Advanced Level
In Physics (WPH15)
Paper 01 Thermodynamics, Radiation, Oscillations and Cosmology

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Summer 2025
Question Paper Log Number P78758A
Publications Code WPH15_01_2506_MS

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:

This mark scheme is published to help teachers and candidates understand the exam requirements. Please note that the mark schemes can be better understood when viewed alongside the question paper and the Principal Examiner Report for Teachers.

It's important to emphasise that a mark scheme is a work in progress that can be further refined and expanded based on students' responses to a particular paper.

It is important to avoid making assumptions about future mark schemes based on a document from one year.

Although the guiding principles of assessment remain constant, the details may vary based on the content of a particular examination paper.

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. '<u>resonance</u>'
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.

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.

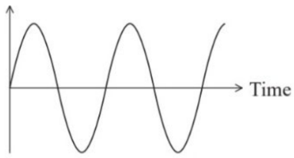
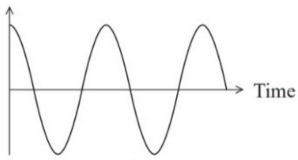
6.3 A mark given for choosing a scale requires that the chosen scale allows all points to be plotted, spreads plotted points over more than half of each axis and is not an awkward scale e.g. multiples of 3, 7 etc.

6.4 Points should be plotted to within 1 mm.

- Check the two points furthest from the best line. If both OK award the 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 D (Field strength is inversely proportional to (distance from the centre of each field)^2.)** A is not correct because an electric field only exerts a force on charged particles B is not correct because a gravitational force is always attractive C is not correct because Field strength $\propto 1/x^2$	**1**
2	**The only correct answer is B (The frequency of oscillation of the mass is a maximum.)** A is not correct because at resonance the amplitude of oscillation is a maximum C is not correct because at resonance mass is being driven at its natural frequency D is not correct because at resonance the transfer of energy is a maximum	**1**
3	**The only correct answer is D (B.E. / nucleon increases in fission and fusion)** A is not correct because B.E. / nucleon increases for both fusion and fission B is not correct because B.E. / nucleon increases for fusion C is not correct because B.E. / nucleon increases for fission	**1**
4	**The only correct answer is D ($\frac{3.1 \times 10^{22}}{74 \times 10^3}$)** A is not correct because the Hubble constant has been divided by the distance in m and km has not been converted to m B is not correct because the Hubble constant has been divided by the distance in m C is not correct because km has not been converted to m	**1**
5	**The only correct answer is A (451 nm)** B is not correct because this would be λ for a galaxy receding at 0.05 c C is not correct because this would be λ for a galaxy at rest relative to the Earth D is not correct because this would be λ for an approaching galaxy	**1**
6	**The only correct answer is B ($\left(\frac{54-22}{4}\right) + 22$)** A is not correct because inverse square law has not been applied correctly C is not correct because neither inverse square law nor correction for background has not been applied correctly D is not correct because correction for background has not been applied correctly	**1**
7	**The only correct answer is C (0.13 I_0)** A is not correct because the absorption calculation assumes a linear absorption B is not correct because this would be the intensity with 5 cm of absorber D is not correct because this would be the intensity with 10 cm of absorber	**1**

8	**The only correct answer is A (Star X has a higher surface temperature and is closer than star Y.)** B is not correct because star X has a higher surface temperature than star Y C is not correct because star X has a higher intensity than star Y D is not correct because star X has a higher surface temperature **and** a higher intensity than star Y	**1**
9	**The only correct answer is D**  A is not correct because the phase difference between the oscillations is incorrect B is not correct because there is no phase difference between the oscillations C is not correct because the phase difference between the oscillations is incorrect	**1**
10	**The only correct answer is A**  B is not correct because the phase difference between the oscillations is incorrect C is not correct because the phase difference between the oscillations is incorrect D is not correct because the phase difference between the oscillations is incorrect	**1**

Question Number	Acceptable Answer		Additional Guidance	Mark
11	Use of $T = 2\pi\sqrt{\frac{m}{k}}$	**(1)**		
	72 kg used to calculate combined mass	**(1)**	Must see the combined mass used	
	$T = 2.2$ s	**(1)**		**3**
			<u>Example of calculation</u> $1.50\text{ s} = 2\pi\sqrt{\frac{67\text{ kg}}{k}}$ $k = \frac{4\pi^2 \times 67\text{ kg}}{(1.50\text{ s})^2} = 1176\text{ N m}^{-1}$ $T = 2\pi\sqrt{\frac{(67+72)\text{ kg}}{1176\text{ N m}^{-1}}} = 2.16\text{ s}$ Ratio method: $\frac{T_2}{T_1} = \sqrt{\frac{m_2}{m_1}}$ $\frac{T_2}{1.50\text{ s}} = \sqrt{\frac{(67+72)\text{ kg}}{67\text{ kg}}}$ $T_2 = \sqrt{\frac{139\text{ kg}}{67\text{ kg}}} \times 1.5\text{ s} = 2.16\text{ s}$	

(Total for Question 11 = 3 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
12	Attempt at criticising student's statement i.e. at least one statement correctly criticised **(1)** MAX 3 from: The alpha tracks are thick because the alpha particles are highly ionising **(1)** The alpha tracks are straight because the alpha particles are massive **(1)** The beta tracks are thin because beta particles are not very ionising **(1)** Beta tracks are twisted because the beta particles have a lower/small mass **(1)** Beta particles cause less ionisation than alpha particles **(1)**	Also credit a statement such as: The reason for the twisted beta tracks is the only correct statement	**4**

(Total for Question 12 = 4 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
13(a)	Use of $V_{\text{grav}} = (-)\frac{GM}{r}$ **(1)** Use of $E_{\text{grav}} = m \times V_{\text{grav}}$ **(1)** $\Delta E_{\text{grav}} = (-)3.5 \times 10^{11}$ J **(1)**	Do not award MP3 if radius of satellite is added to radius of Earth [final answer is 3.54×10^{11} J] Do **not** credit approaches based on use of $\Delta E_{\text{grav}} = mg\Delta h$ <u>Example of calculation</u> $\Delta V_{\text{grav}} = 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 5.98 \times 10^{24}\text{ kg} \times \left(\frac{1}{6.37 \times 10^{6}\text{ m}} - \frac{1}{4.22 \times 10^{7}\text{m}}\right)$ $\Delta V_{\text{grav}} = -5.32 \times 10^{7}\text{ J kg}^{-1}$ $\Delta E_{\text{grav}} = 6500\text{ kg} \times (-5.32 \times 10^{7}\text{ J kg}^{-1}) = -3.46 \times 10^{11}\text{ J}$ $\Delta E_{\text{grav}} = -3.46 \times 10^{11}\text{ J}$	3

Question Number	Answer		Mark
13(b)	Gravitational force equated to centripetal force **(1)** Use of $\omega = \frac{2\pi}{T}$ **Or** Use of $v = \frac{2\pi r}{T}$ **(1)** $T = 8.62 \times 10^4$ (s) **Or** $v = 3070$ m s^{-1} **Or** $\omega = 7.29 \times 10^{-5}$ rad s^{-1} **(1)** 8.62×10^4 (s) $\approx 8.64 \times 10^4$ (s), so yes (it would appear stationary above the Earth's surface) **Or** Calculated value of T compared with 8.64×10^4 (s) and consistent conclusion made **Or** 3070 m s^{-1} = 3070 m s^{-1}, so (satellite would move with the Earth and) appear stationary above the Earth's surface **Or** $\omega = 7.29 \times 10^{-5}$ rad s^{-1} $\approx 7.27 \times 10^{-5}$ rad s^{-1}, so (satellite would move with the Earth and) appear stationary above the Earth's surface **Or** centripetal force ≈ gravitational force, so (satellite would move with the Earth and) appear stationary above the Earth's surface **(1)**	<u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $\therefore \omega = \sqrt{\frac{GM}{r^3}}$ $\omega = \sqrt{\frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 5.98 \times 10^{24}\ \text{kg}}{(4.22 \times 10^7\ \text{m})^3}}$ $\omega = 7.29 \times 10^{-5}\ \text{rad s}^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi\ \text{rad}}{7.29 \times 10^{-5}\ \text{rad s}^{-1}} = 8.62 \times 10^4\ \text{s}$ $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $v = \sqrt{\frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 5.98 \times 10^{24}\ \text{kg}}{(4.22 \times 10^7\ \text{m})}}$ $v = 3074\ \text{m s}^{-1}$ $v = \frac{2\pi r}{T} = \frac{2\pi \times 4.22 \times 10^7\ \text{m}}{8.64 \times 10^4\ \text{s}} = 3069\ \text{m s}^{-1}$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{8.64 \times 10^4\ \text{s}} = 7.27 \times 10^{-5}\ \text{rad s}^{-1}$	4

(Total for Question 13 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
14(a)	The parallax angle decreases the further the object is from the Earth **Or** For (very) distant objects the parallax angle is very small **(1)** The measuring instrument is not sensitive enough **Or** The measurement is not accurate enough **Or** The (percentage) uncertainty in the measurement is too high **(1)**	Allow converse statement for close objects Accept 'The angle is too small' Idea that angle can't be read from scale, not that the star can't be seen	**2**
14(b)(i)	A standard candle is a (stellar) object of known luminosity **(1)**	Do **not** accept 'intensity' or 'brightness' for 'luminosity' If known distance/intensity/flux is also specified, do not give the mark	**1**
14(b)(ii)	A description that makes reference to the following points: Standard candle is located (in the star cluster) **(1)** Intensity of radiation received from the candle is measured (on Earth) **(1)** Inverse square law is used (with luminosity of standard candle) to determine the distance to the star cluster **Or** $I = \frac{L}{4\pi d^2}$ is used [I and L must be defined] **(1)**	Allow 'radiation flux' for 'intensity' Accept 'determined', but reject 'calculated'	**3**

(Total for Question 14 = 6 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
15(a)	There is a (resultant) acceleration / force that is proportional to the displacement from the equilibrium point/position **(1)** and (always) acting towards the equilibrium point/position **(1)**	Reject 'equilibrium', but allow **1 MAX** if point/position omitted in both MP. For equilibrium position accept: undisplaced point/position **Or** fixed point/position **Or** central point/position Allow 'in the opposite direction (to displacement)' An equation with symbols defined correctly is a valid response for both marks	**2**

15(b)	**EITHER** T = 0.40 s **and** A = 3.0 cm read from graph **(1)** Use of $\omega = \frac{2\pi}{T}$ **(1)** Use of $v = (-)A\omega \sin \omega t$ with $\sin \omega t = 1$ **(1)** $v = 0.47 \text{ m s}^{-1}$ **(1)** **OR** Tangent drawn to curve at point where y = 0 **(1)** Pair of corresponding values read from graph **(1)** Gradient calculated **(1)** $v = 0.50 \text{ m s}^{-1}$ **(1)**	Use of $v = (-)A\omega$ is fine Allow answers between 0.45 and 0.55 <u>Example of calculation</u> $\omega = \frac{2\pi \text{ rad}}{0.40 \text{ s}} = 15.7 \text{ rad s}^{-1}$ $v = 3.0 \times 10^{-2} \text{ m} \times 15.7 \text{ s}^{-1} \times 1 = 0.471 \text{ m s}^{-1}$	4
15(c)	Energy is transferred away from the car body **Or** energy is transferred/dissipated to the surroundings **Or** thermal energy store (of dampers) increases **(1)** (Because) work is done against resistive forces **(1)**	Allow 'oscillating system' for 'car body' Allow 'thermal energy is produced in the dampers' Allow 'heat' for 'thermal energy' Allow **1 MAX** for 'energy dissipation due to resistive forces'	2

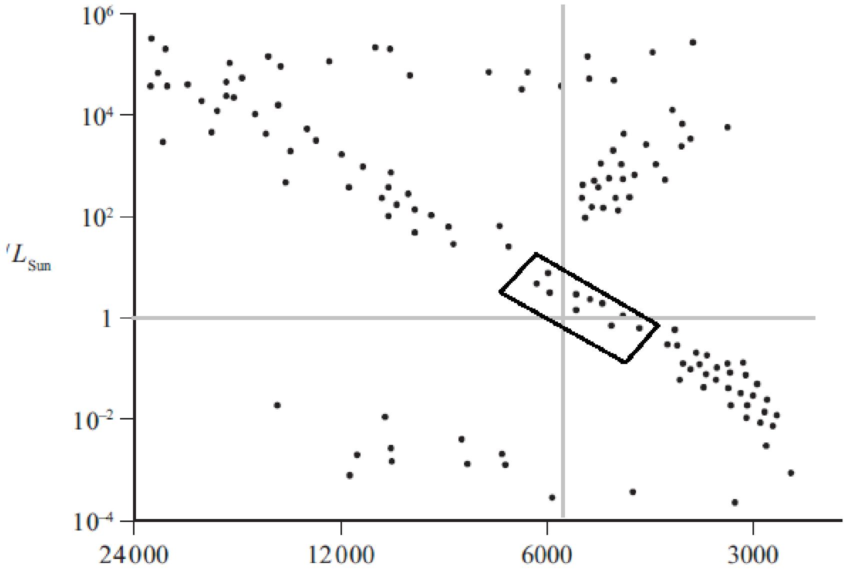
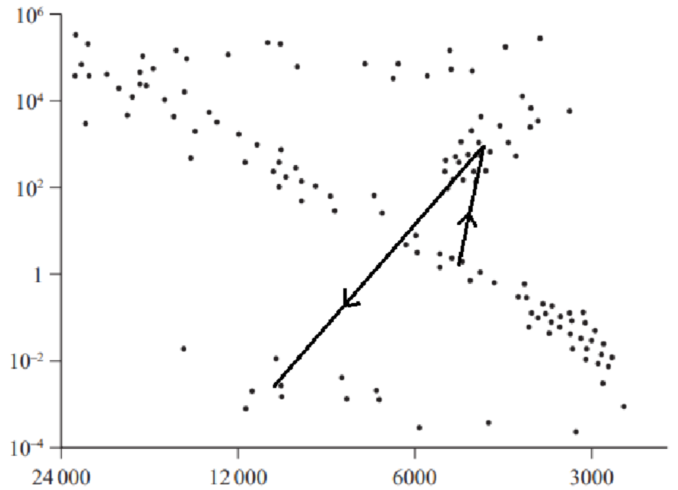
(Total for Question 15 = 8 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
16(a)	Volume of block calculated **(1)** Use of $\rho = \frac{m}{V}$ **(1)** Use of $\Delta E = mc\Delta\theta$ **(1)** Use of $\Delta E = mL$ **(1)** $\Delta E = 1.84 \times 10^5$ J **(1)**	<u>Example of calculation</u> $V = 25 \times 10^{-2}\ \text{m} \times 15 \times 10^{-2}\ \text{m} \times 1.5 \times 10^{-2}\ \text{m}$ $V = 5.63 \times 10^{-4}\ \text{m}^3$ $m = 920\ \text{kg m}^{-3} \times 5.63 \times 10^{-4}\ \text{m}^3 = 0.518\ \text{kg}$ $\Delta E = (0.52\ \text{kg} \times 2100\ \text{J kg}^{-1}\ \text{K}^{-1} \times 7.5\ \text{K})$ $+ (0.52\ \text{kg} \times 3.4 \times 10^5\ \text{J kg}^{-1})$ $\Delta E = 8190\ \text{J} + 1.77 \times 10^5\ \text{J} = 1.84 \times 10^5\ \text{J}$	**5**
16(b)	(Latent heat) energy must be supplied to melt the ice **(1)** Energy has been transferred from the food/surroundings to the ice **Or** Energy has **not** been transferred from the ice to the food **(1)**		**2**

(Total for Question 16 = 7 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
17(a)	Substitute into $V = \frac{4}{3}\pi r^3$ Use of $pV = NkT$ Conversion of temperature to kelvin Use of number of molecules to calculate mass of gas $m = 230$ kg	(1) (1) (1) (1) (1)	Do not credit $pV = nRT$ unless final answer is correct If answer incorrect, *could* award marks for MP1, MP3, MP4 <u>Example of calculation</u> $V = \frac{4}{3}\pi \times (3.5\text{ m})^3 = 179.6\text{ m}^3$ $N = \frac{1.12 \times 10^5\text{ Pa} \times 179.6\text{ m}^3}{1.38 \times 10^{-23}\text{J K}^{-1} \times (273 + 22)\text{ K}} = 4.94 \times 10^{27}$ $m = 4.94 \times 10^{27} \times 4.67 \times 10^{-26}\text{ kg} = 231\text{ kg}$	5
17(b)	Use of $\omega = \frac{2\pi}{T}$ $T = 228$ s	(1) (1)	<u>Example of calculation</u> $T = \frac{2\pi\text{ rad}}{2.76 \times 10^{-2}\text{ rad s}^{-1}} = 227.6\text{ s}$	2
17(c)	Use of $g = \frac{GM}{r^2}$ $M = 1.8 \times 10^{12}$ kg	(1) (1)	<u>Example of calculation</u> $M = \frac{gr^2}{G} = \frac{9.8\text{ N kg}^{-1} \times (3.5\text{ m})^2}{6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2}} = 1.80 \times 10^{12}\text{ kg}$	2

(Total for Question 17 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
18(a)(i)	Sun marked where luminosity ≈ 1 and within marked main sequence region **(1)**	 Allow any part of S within the approximate area shown	**1**
18(a)(ii)	Line from S to red giant region **(1)** Line from red giant region to white dwarf region **(1)**	 If S is not marked, then arrows needed to show direction Allow arrow from their position of Sun to red giant region	**2**

***18(b)**

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.

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 Hydrogen is being fused in <u>core</u> of the Sun

IC2 When hydrogen (in core) is used up and (rate of) fusion decreases/ceases

IC3 The <u>core</u> collapses / contracts (under gravitational forces)

IC4 Temperature rises (high enough) and helium fusion starts

IC5 The Sun expands into a red giant

IC6 When no further fusion takes place, core/star collapses (into a white dwarf)

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.

Number of indicative points seen in answer	Number of marks awarded for indicative points
6	4
5-4	3
3-2	2
1	1
0	0

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

IC4: Must be temperature rise to start helium fusion not temperature rises after helium fusion starts.

6

18(c)

Massive main sequence stars have (much) higher temperatures (than the Sun) **(1)**

Allow the Sun has a (much) lower temperature (than massive main sequence stars), ignore references to density

Hydrogen is fused at a greater rate than in the Sun (so the time spent on the main sequence is less) **(1)**

Must have the idea of 'rate of fusion'

2

(Total for Question 18 = 11 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
19(a)(i)	Use of $c = f\lambda$ Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $T = 5310$ (K)	(1) (1) (1)	<u>Example of calculation</u> $\lambda = \frac{3.0 \times 10^8 \text{ m s}^{-1}}{5.50 \times 10^{14} \text{ Hz}} = 5.45 \times 10^{-7}$ m $T = \frac{2.898 \times 10^{-3} \text{ m K}}{5.45 \times 10^{-7} \text{ m}} = 5313$ K	**3**
19(a)(ii)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ $\frac{1}{2}m\langle c^2\rangle = 1.10 \times 10^{-19}$ J [ecf for T from (a)(i)]	(1) (1)	<u>Example of calculation</u> $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2} \times 1.38 \times 10^{-23}$ J K^{-1} $\times$ 5310 K $= 1.099 \times 10^{-19}$ J	**2**
19(b)	Use of $A = 4\pi r^2$ Use of $L = \sigma A T^4$ Use of $I = \frac{L}{4\pi d^2}$ $I = 2120$ (W m^{-2}) [ecf for T from (a)(i)] 2120 (W m^{-2}) > 1360 (W m^{-2}) so suggestion is not accurate **Or** Calculated intensity compared with 1360 (W m^{-2}) with conclusion **Or** 1.72×10^{26} W >1.11×10^{26} W so suggestion is not accurate	(1) (1) (1) (1) (1)	<u>Example of calculation</u> $I = \frac{4\pi r^2 \sigma T^4}{4\pi x^2}$ $I = \frac{4\pi \times (5.52 \times 10^8 \text{ m})^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (5310)^4}{4\pi \times (8.05 \times 10^{10} \text{ m})^2}$ $\therefore I = 2120$ W m^{-2} 2120 (W m^{-2}) > 1360 (W m^{-2}) so suggestion is inaccurate $L = (5.52 \times 10^8 \text{ m})^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (5310)^4$ $L = 1.72 \times 10^{26}$ W $1360 \text{ W m}^{-2} = \frac{L}{4\pi \times (8.05 \times 10^{10} \text{ m})^2}$ $L = 4\pi \times (8.05 \times 10^{10} \text{ m})^2 \times 1360 \text{ W m}^{-2} = 1.11 \times 10^{26}$ W	**5**

(Total for Question 19 = 10 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
20(a)	Top line correct **(1)** Bottom line correct **(1)**	Example of calculation $^{238}_{94}\text{Pu} \rightarrow {}^{234}_{92}\text{U} + {}^{4}_{2}\alpha$	**2**
20(b)(i)	Calculation of mass difference **(1)** Use of $\Delta E = c^2 \Delta m$ **(1)** Conversion from J to eV **(1)** $\Delta E = 5.68$ (MeV) **(1)**	Number of plutonium atoms in 1 kg may be calculated by using 3.9516×10^{-25} kg from (a) . Example of calculation $\Delta m = (3.8851 \times 10^{-25} + 6.6399 \times 10^{-27} - 3.9516 \times 10^{-25})$ kg $\Delta m = (-)1.01 \times 10^{-29}$ kg $\Delta E = (3.0 \times 10^{8}\ \text{m s}^{-1})^2 \times 1.01 \times 10^{-29}$ kg $= 9.09 \times 10^{-13}$ J $\Delta E = \dfrac{9.09 \times 10^{-13}\ \text{J}}{1.6 \times 10^{-19}\text{J eV}^{-1}} = 5.68 \times 10^{6}\ \text{eV} = 5.68\ \text{MeV}$	**4**

20(b)(ii)	**EITHER** Calculation of number of plutonium atoms **(1)** Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ **(1)** Use of $A = \lambda N$ **(1)** Rate of energy release = 575 W [ecf from (b)(i)] **(1)** 575 W ≈ 550 W, so website statement is accurate **Or** Calculated value compared with value in question and consistent conclusion **(1)** **OR** Calculation of activity using power of plutonium decay **(1)** Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ **(1)** Use of $A = \lambda N$ to calculate N **(1)** Mass of plutonium = 0.96 kg [ecf from (b)(i)] **(1)** 0.96 kg ≈ 1.00 kg so website statement is accurate **Or** Calculated value compared with value in question and consistent conclusion **(1)**	<u>Example of calculation</u> $N = \frac{1.000\text{ kg}}{0.238\text{ kg}} \times 6.00 \times 10^{23} = 2.52 \times 10^{24}$ $\lambda = \frac{\ln 2}{(87.7 \times 3.15 \times 10^{7})\text{ s}} = 2.51 \times 10^{-10}\text{ s}^{-1}$ $A = 2.51 \times 10^{-10}\text{ s}^{-1} \times 2.52 \times 10^{24} = 6.33 \times 10^{14}\text{ s}^{-1}$ $P = 6.33 \times 10^{14}\text{ s}^{-1} \times 9.09 \times 10^{-13}\text{ J} = 575\text{ W}$	**5**
20(b)(iii)	Use of $A = A_0 e^{-\lambda t}$ **Or** Use of $N = N_0 e^{-\lambda t}$ **(1)** $P = 550$ W [ecf from (b)(ii)] **(1)**	Power can be substituted instead of activity, but must be calculating final not initial values <u>Example of calculation</u> $P = (575\text{ W})e^{-2.51 \times 10^{-10}\text{ s}^{-1} \times 74 \times 2.63 \times 10^{6}\text{ s}} = 548\text{ W}$ Use of 550 W leads to value of 525 W	**2**

20(c)	Intensity obeys an inverse square law **Or** Intensity is given by $I = \frac{L}{4\pi d^2}$ (So) the power/intensity (incident on the solar cells) would be too small **Or** power/intensity would be much less (than for Mars probe) **Or** (output) power from solar cells would be too small **Or** solar panels would need to be too large	**(1)** **(1)**	 [MP2 dependent upon MP1]	**2**

(Total for Question 20 = 15 marks)

TOTAL FOR PAPER = 90 MARKS

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom