Pearson Edexcel

Mark Scheme (Results)

January 2022

Pearson Edexcel International Advanced Subsidiary Level In Physics (WPH15) Paper 01 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.

Question Number	Answer	Mark
1	**B is the correct answer,** as this is part of the definition of s.h.m.	**(1)**
2	**B is the correct answer** A is incorrect, as this would increase the value of L_V C is incorrect, as it's not necessary to stir boiling water D is incorrect, as this would increase the value of L_V	**(1)**
3	**D is the correct answer,** as $T = 2\pi\sqrt{\frac{L}{g}}$ and $T = 2 \times 8.25$s	**(1)**
4	**C is the correct answer,** as the activity halves in each half-life period	**(1)**
5	**A is the correct answer,** as $pV \propto T$	**(1)**
6	**D is the correct answer,** as this is a statement of Hubble's law	**(1)**
7	**B is the correct answer** A is incorrect, as background count rate varies from place to place C is incorrect, as the background count is not constant D is incorrect, as some detector are more sensitive than others	**(1)**
8	**B is the correct answer,** as $I = \frac{L}{4\pi d^2}$	**(1)**
9	**B is the correct answer** A is incorrect, as the lines may be shifted into any region of the spectrum C is incorrect, as the intensity of the lines is not related to the redshift D is incorrect, as the wavelengths of the emitted lines is not affected	**(1)**
10	**D is the correct answer,** A is incorrect, as 56Fe is the most stable isotope B is incorrect, as the graph shows the binding energy per nucleon C is incorrect, as high mass nuclei could be fused as long as energy is supplied	**(1)**

Question Number	Answer		Mark
11	At least 1 cycle of a sinusoidal graph	(1)	
	Displacement axis shows amplitude as 5 cm	(1)	
	Use of $a = (-)\omega^2 x$ and $\omega = \frac{2\pi}{T}$ to calculate T	(1)	
	Time axis shows period as calculated value of T	(1)	**4**
	<u>Example of calculation</u> $\omega = \sqrt{\frac{8.0\text{ cm s}^{-2}}{5.0\text{ cm}}} = 1.26\text{ s}^{-1}$ $T = \frac{2\pi}{1.26\text{ s}^{-1}} = 4.97\text{ s}$		
	Total for question 11		**4**

Question Number	Answer		Mark
12	Energy transferred from hot liquid = energy transferred to ice + energy transferred to cold water	(1)	
	[This may be implicit]		
	Use of $E = mc\Delta\theta$	(1)	
	Use of $E = mL$	(1)	
	Mass of ice required to cool drink to 58 ºC is 2.4×10^{-2} kg **Or** Final temperature using 4 g of ice is 69 ºC	(1)	
	Valid conclusion based on a consideration of their calculated value in comparison with a corresponding value in the question.	(1)	**5**
	<u>Example of calculation</u> Energy transferred from hot liquid = energy transferred to ice + energy transferred to cold water $0.275 \text{ kg} \times 3750 \text{ J kg}^{-1}\text{K}^{-1} \times (71.5 - 58.0)\text{K}$ $= \text{m} \times 3.34 \times 10^5 \text{ J kg}^{-1} + \text{m} \times 4190 \text{ J kg}^{-1}\text{K}^{-1} \times (58.0 - 0)\text{K}$ $\therefore 1.39 \times 10^4\text{J} = \text{m} \times (3.34 \times 10^5 + 2.43 \times 10^5) \text{ J kg}^{-1}$ $\therefore m = \frac{1.39\times10^4 \text{ J}}{5.77\times10^5 \text{ J kg}^{-1}} = 2.41 \times 10^{-2}$ kg = 24 g So 4 g would not bring the temperature below the ideal serving temperature.		
	Total for question 12		**5**

Question Number	Answer	Mark
13(a)	Use of $pV = NkT$ (1) Temperature converted to kelvin (1) $V = 6.9\ \text{m}^3$ (1) <u>Example of calculation</u> $\frac{pV}{T} = \text{a constant}$ $\frac{8.4 \times 10^4\ \text{Pa} \times V}{(273 - 48)\ \text{K}} = \frac{1.02 \times 10^5\ \text{Pa} \times 7.50\ \text{m}^3}{(273 + 22.5)\text{K}}$ $\therefore V = \frac{1.02 \times 10^5\ \text{Pa} \times 7.5\ \text{m}^3 \times (273 - 48)\ \text{K}}{(273 + 22.5)\text{K} \times 8.4 \times 10^4\ \text{Pa}} = 6.93\ \text{m}^3$	**3**
13(b)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ (1) Decrease = 1.5×10^{-21} J (1) <u>Example of calculation</u> $\Delta(\text{mean kinetic energy}) = \frac{3}{2}1.38\ \times 10^{-2}\ \ \text{J K}^{-1}(-48 - 22.5)\text{K}$ $\therefore \Delta(\text{mean kinetic energy}) = -1.46 \times 10^{-21}\ \text{J}$	**2**
	Total for question 13	**5**

Question Number	Answer	Mark
14	Max kinetic energy read from graph (1) Use of 15.6 eV to calculate number of nitrogen molecules ionised (1) Use of 250 to calculate range of β particle (1) Range of β particle read from graph (1) Comparison of their two ranges with conclusion (1) **OR** Max kinetic energy read from graph (1) Use of 15.6 eV to calculate number of nitrogen molecules ionised (1) Range of β particle read from graph (1) Use of range to calculate number of molecules ionised (1) Comparison of their two numbers of molecules with conclusion (1) <u>Example of calculation</u> Maximum E_k = 0.52 MeV→ 0.55 MeV $N = \frac{5.3 \times 10^5 \text{eV}}{15.6 \text{ eV}} = 3.40 \times 10^4$ $\text{Range} = \frac{3.40 \times 10^4}{250 \text{ cm}^{-1}} = 136 \text{ cm} = 1.36 \text{ m}$ Range of β particle = 1.2 m → 1.4 m	**5**
	Total for question 14	**5**

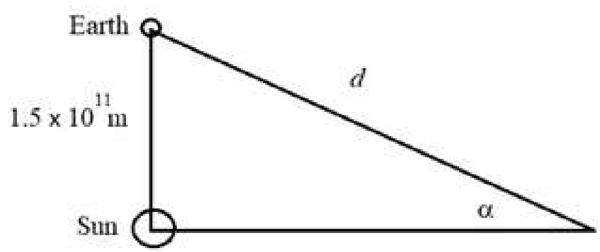
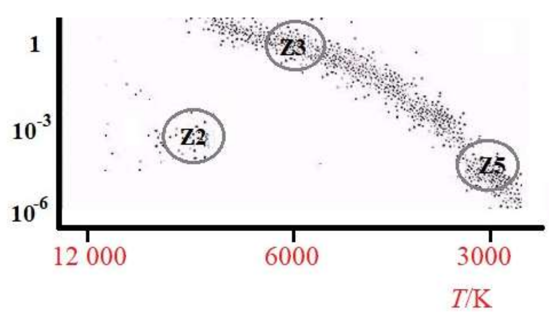
Question Number	Answer		Mark
15	λ_{max} read from graph [450 nm → 500 nm] Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K Use of $L = \sigma AT^4$ Use of $A = 4\pi r^2$ $D_P = 4.6 \times D_{Sun}$ so statement is incorrect Or $D_P = 3.2 \times 10^9$ m, which is more than twice Sun's diameter, so statement is incorrect <u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3}\text{ m K}}{470 \times 10^{-9}\text{ nm}} = 6170\text{ K}$ $A = \frac{2.65 \times 10^{27}\text{ W}}{5.67 \times 10^{-8}\text{ W m}^{-2}\text{ K}^4 \times (6170\text{ K})^4} = 3.22 \times 10^{19}\text{ m}^2$ $r = \sqrt{\frac{3.22 \times 10^{19}\text{ m}^2}{4\pi}} = 1.60 \times 10^9\text{ m}$ $\frac{D_P}{D_{Sun}} = \frac{2 \times 1.60 \times 10^9\text{ m}}{6.96 \times 10^8\text{ m}} = 4.6$	(1) (1) (1) (1) (1)	5
	Total for question 15		**5**

Question Number	Answer		Mark
16(a)(i)	$v \propto \sqrt{\frac{M}{r}}$ Within the central region *M* changes a lot (so *v* increases) **Or** Outside the central region *M* is approximately constant (so *v* decreases) As *r* increases *v* reaches a peak value as shown on the graph [A bald description of the graph having a peak value can score MP3]	(1) (1) (1)	**3**
16(a)(ii)	There must be more mass (than we can observe) [Accept statement that there must be a greater gravitational force] There is dark matter present (in the galaxy)	(1) (1)	**2**
16(b)	(For a closed universe) the density of the universe must be greater than the critical density And the (average) density of the universe is uncertain **Or** the amount of dark matter is uncertain	(1) (1)	**2**
	Total for question 16		**7**

Question Number	Answer		Mark
17(a)	**Either** Current carrying coil/conductor in a magnetic field Coil experiences a force Force changes direction with current (as current is changing direction) **Or** Current in coil causes a magnetic field Field interacts with permanent magnet's field, so force on coil Field changes direction with current so force changes direction	 (1) (1) (1) (1) (1) (1)	**3**
17(b)(i)	Use of $\omega = 2\pi f$ Use of $v = -A\omega \sin \omega t$ $v = 0.82 \text{ m s}^{-1}$ Example of calculation $\omega = 2\pi \text{ rad} \times 75 \text{ s}^{-1} = 471 \text{ rad s}^{-1}$ $v = 1.75 \times 10^{-3} \text{m} \times 471 \text{ s}^{-1} \times 1 = 0.8247 \text{ m s}^{-1}$	(1) (1) (1)	**3**
17(b)(ii)	At the equilibrium/undisplaced/central/middle (position)	(1)	**1**
17(c)	**MAX 2** The driver frequency of the coil matches the natural frequency of the cone There is a maximum transfer of energy (from the coil to the cone) Resonance occurs [For full marks the response must be related to the question context]	 (1) (1) (1)	**2**
	Total for question 17		**9**

Question Number	Answer		Mark
18(a)	Use of $T^2 = KR^3$	(1)	
	K for Earth = 2.96×10^{-19} ($s^2\ m^{-3}$)	(1)	
	K for Mars = 2.97×10^{-1} ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation $K = \frac{T^2}{R^3} = \frac{(3.16 \text{ x } 10^7 \text{s})^2}{(1.50 \text{ x } 10^{11} \text{ m})^3} = 2.959 \times 10^{-19}\ \text{s}^2\ \text{m}^{-3}$ $K = \frac{T^2}{R^3} = \frac{(5.93 \text{ x } 10^7 \text{s})^2}{(2.28 \text{ x } 10^{11} \text{ m})^3} = 2.967 \times 10^{-19}\ \text{s}^2\ \text{m}^{-3}$		
18(b)	**Either**		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to identify *K* as $\frac{(2\pi)^2}{GM}$	(1)	
	K = 2.97×10^{-19} ($s^2\ m^{-3}$)	(1)	
	Or		
	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to identify *K* as $\frac{(2\pi)^2}{GM}$	(1)	
	K = 2.97×10^{-19} ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation $\frac{GMm}{r^2} = m\omega^2 r$ $\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$ $T^2 = \frac{(2\pi)^2}{GM} r^3$ $K = \left(\frac{4\pi^2}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 1.99 \times 10^{30}\ \text{kg}}\right) = 2.97 \times 10^{-1}\ \ \text{s}^2\text{m}^{-3}$		

18(c)	Use of $T^2 = KR^3$ (1) T = 43 hours (1) <u>Example of calculation</u> $\left(\frac{T_I}{T_G}\right)^2 = \left(\frac{R_I}{R_G}\right)^3$ $T = \sqrt{\left(\frac{4.22 \times 10^8 \text{ m}}{1.07 \times 10^9 \text{ m}}\right)^3 \times (172 \text{ hour})^2} = 42.6 \text{ hours}$		**2**
	Total for question 18		**8**

Question Number	Answer	Mark
19(a)	Use of trigonometry to calculate the parallax angle **Or** Use of trigonometry to calculate distance (1) (Smallest) parallax angle = 3.3×10^{-7} (rad) **Or** max distance = 6.25×10^{17} (m) (1) Comparison of calculated value with corresponding value in question with valid conclusion (1) Example of calculation $\sin\alpha = \frac{1.5 \times 10^{11}\ \text{m}}{d}$ $\alpha = \sin^{-1}\left(\frac{1.5 \times 10^{11}\ \text{m}}{4.6 \times 10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad **Or** $\alpha = \left(\frac{1.5\times10^{11}\ \text{m}}{4.6\times10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad (small angle approximation)  	3
19(b)	The intensity (of radiation from the candle) is measured (1) The luminosity of the standard candle is known (1) The inverse square law is used to determine the distance [Accept reference to $I=L/4\pi d^2$ with symbols defined] (1)	3
19(c)(i)	Axis labelled with T / K (1) Reverse logarithmic scale (1) 6000 K in correct position on scale (1) Example of graph labelling  	3

19(c)(ii)	<table><tr><th>Description</th><th>Zone</th></tr><tr><td>High mass hot stars</td><td>Z1</td></tr><tr><td>Low mass cool stars</td><td>Z5</td></tr><tr><td>Low mass hot stars</td><td>Z2</td></tr></table> (1) (1) (1)	**3**

19(c)(iii)

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for structure and 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

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 The star is fusing hydrogen in its core

IC2 When fusion ceases (the core of the star cools and) the core collapses/contracts (under gravitational forces)

IC3 The star (moves to Z4 as it expands and) becomes a red giant star

IC4 Temperature (in the core) is high enough for helium fusion to begin

IC5 Helium begins to run out and then fusion ceases

IC6 The star becomes a white dwarf (in Z2)

6

	Total for question 18	**18**

Question Number	Answer		Mark
20(a)	Top row correct	(1)	
	Bottom row correct	(1)	**2**
	Example of calculation $^{225}_{89}\text{Ac} \rightarrow {}^{221}_{87}\text{Fr} + {}^{4}_{2}\alpha$		
20(b)	Use of 1 u = 1.66×10^{-27} kg	(1)	
	Use of $\Delta E = c^2 \Delta m$	(1)	
	Use of 1 J = 1.6×10^{-19} eV	(1)	
	1 u = 934 (MeV)	(1)	**4**
	Example of calculation $\Delta E = (3.0 \times 10^8 \text{ m s}^{-1})^2 \times 1.66 \times 10^{-27} \text{ kg} = 1.494 \times 10^{-10} \text{ J}$ $\therefore \Delta E = \frac{1.494 \times 10^{-10} \text{ J}}{1.6 \times 10^{-13} \text{ J MeV}^{-1}} = 934 \text{ MeV}$		
20(c)	Use of 1 u = 934 MeV (ecf from (b) [Accept calculation from first principles]	(1)	
	The mass of the Fr nucleus is much greater than the mass of the α	(1)	
	Momentum is conserved so (recoil) velocity of Fr nucleus is much less than the velocity of the α	(1)	
	So the kinetic energy of the α is much greater than the kinetic energy of the Fr **Or** (after the decay) the α has most of the kinetic energy [MP4 dependent upon MP2 or MP3]	(1)	
	OR		
	Use of 1 u = 934 MeV (ecf from (b) [Accept calculation from first principles]	(1)	
	Mathematical statement of momentum conservation	(1)	
	Use of $E_k = \frac{p^2}{2m}$ **Or** use of $E_k = \frac{1}{2}mv^2$ **and** $p = mv$	(1)	
	E_k calculated and statement that E_k is just less than 5.9 MeV **Or** E_k calculated and statement that α has most of the kinetic energy	(1)	**4**
	Example of calculation $\Delta E = 6.35 \times 10^{-3} \text{ u} \times 934 \text{ MeV u}^{-1} = 5.93 \text{ MeV}$ [5.91 MeV if "show that" value used]		

20(d)	Use of $\lambda t_{1/2} = \ln 2$	(1)	
	Use of $A = -\lambda N$	(1)	
	Use of $N = N_0 e^{-\lambda t}$	(1)	
	$N = 5.6 \times 10^{13}$	(1)	**4**
	<u>Example of calculation</u> $\lambda = \frac{\ln 2}{9.9 \times 24 \times 3600\ \mathrm{s}} = 8.10 \times 10^{-7}\ \mathrm{s}^{-1}$ $N = \frac{7.4 \times 10^{7}\ \mathrm{s}^{-1}}{8.10 \times 10^{-7}\ \mathrm{s}^{-1}} = 9.13 \times 10^{13}$ $N = 9.13 \times 10^{13} \times e^{-8.10 \times 10^{-7}\ \mathrm{s}^{-1} \times 7.0 \times 24 \times 3600\ \mathrm{s}} = 5.59 \times 10^{13}$		
	Total for question 20		**14**

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