Mark Scheme (Results)

January 2024

Pearson Edexcel International Advanced 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 only correct answer** A is not the correct answer, as molecular potential energy increases C is not the correct answer, as molecular kinetic energy doesn't change and molecular potential energy increases D is not the correct answer, as molecular kinetic energy doesn't change	**(1)**
2	**A is the only correct answer** B is not the correct answer, as parallax can only be used for nearby stars C is not the correct answer, as parallax measurements do not involve luminosity D is not the correct answer, as the parallax effect is greatest for nearby stars	**(1)**
3	**C is the only correct answer,** as the mass-energy equivalent is calculated by converting the mass to kg and then using $\Delta E = c^2 \Delta m$	**(1)**
4	**D is the only correct answer** A is not the correct answer, as acceleration can be in the same or the opposite direction to velocity B is not the correct answer, as acceleration can be in the same or the opposite direction to velocity C is not the correct answer, as acceleration is always towards the equilibrium point	**(1)**
5	**C is the only correct answer** A is not the correct answer, as this does not make the process spontaneous B is not the correct answer, as this does not make the process spontaneous D is not the correct answer, as this does not make the process spontaneous	**(1)**
6	**B is the only correct answer** A is not the correct answer, as speed increases C is not the correct answer, as gravitational potential energy decreases and speed increases D is not the correct answer, as gravitational potential energy decreases	**(1)**
7	**B is the only correct answer,** as $v_{\text{max}} = \omega A$	**(1)**
8	**D is the only correct answer** A is not the correct answer, as the mean kinetic energy is the same for both gases B is not the correct answer, as the mean kinetic energy is the same for both gases C is not the correct answer, as He molecules are more massive than H molecules	**(1)**
9	**D is the only correct answer** A is not the correct answer, as the peak for star Y is at the higher frequency B is not the correct answer, as the peak for star Y is at the lower frequency C is not the correct answer, as the peak for star X is at the higher frequency	**(1)**
10	**A is the only correct answer,** as $g = \frac{GM}{r^2}$	**(1)**

Question Number	Answer		Mark
11	Stars in area P are (massive) main sequence stars	**(1)**	
	Stars in area P evolve into area S **and** stars in area S evolve into area Q [Allow P → S → Q, or arrows on diagram]	**(1)**	
	Stars in area S are red giant stars **and** stars in area Q are white dwarf stars [accept red supergiant for red giant]	**(1)**	**3**
	Total for question 11		**3**

Question Number	Answer		Mark
12	**EITHER**		
	Use of $g = \frac{GM}{r^2}$	**(1)**	
	Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ with $g = 9.81\ \mathrm{N\ kg^{-1}}$ to calculate length [$\ell = 0.994\ \mathrm{m}$]	**(1)**	
	Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ with g_{venus} to calculate period	**(1)**	
	$T_{\mathrm{Venus}} = 2.1\ \mathrm{s}$ [Do not accept 2.0 s]	**(1)**	
	OR		
	Use of $g = \frac{GM}{r^2}$	**(1)**	
	Ratio of periods with $T = 2\pi\sqrt{\frac{\ell}{g}}$	**(1)**	
	Re-arrangement to obtain $\frac{T_{\mathrm{Venus}}}{T_{\mathrm{Earth}}} = \sqrt{\frac{g_{\mathrm{Earth}}}{g_{Mars}}}$	**(1)**	
	$T_{\mathrm{Venus}} = 2.1\ \mathrm{s}$ [Do not accept 2.0 s]	**(1)**	**4**
	Example of calculation $g = \frac{6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}} \times 4.87 \times 10^{24}\ \mathrm{kg}}{(6.05 \times 10^6\ \mathrm{m})^2} = 8.87\ \mathrm{N\ kg^{-1}}$ $\frac{T_{\mathrm{Venus}}}{T_{\mathrm{Earth}}} = \sqrt{\frac{g_{\mathrm{Earth}}}{g_{Mars}}} = \sqrt{\frac{9.81\ \mathrm{N\ kg^{-1}}}{8.87\ \mathrm{N\ kg^{-1}}}} = 1.05$ $T_{\mathrm{Venus}} = 1.05 \times 2.00\ \mathrm{s} = 2.10\ \mathrm{s}$		
	Total for question 12		**4**

Question Number	Answer		Mark
13	**EITHER**		
	Use of $\frac{\Delta f}{f} \approx \frac{v}{c}$ [must have f_{lab} in denominator]	**(1)**	
	$v = (-)1.5 \times 10^6$ m s^{-1}	**(1)**	
	Galaxy is receding (from the Earth)	**(1)**	
	OR		
	Use of $z = \frac{\Delta f}{f}$ [must have f_{lab} in denominator]	**(1)**	
	$z = (-)\ 5.0 \times 10^{-3}$	**(1)**	
	Galaxy is receding (from the Earth)	**(1)**	**3**
	<u>Example of calculation</u> $v = 3.0 \times 10^8 \text{ m s}^{-1} \times \left(\frac{6.142 \times 10^{14}\text{Hz} - 6.173 \times 10^{14}\text{ Hz}}{6.173 \times 10^{14}\text{ Hz}}\right) = -1.51 \times 10^6 \text{ m s}^{-1}$		
	Total for question 13		**3**

Question Number	Answer		Mark
14	Use of mass of molecule to calculate N	**(1)**	
	Use of $pV = NkT$	**(1)**	
	Conversion of temperature to kelvin	**(1)**	
	Difference in pressures calculated	**(1)**	
	$\Delta p = 3.6 \times 10^4$ Pa	**(1)**	**5**
	<u>Example of calculation</u> $N = \frac{2.00 \times 10^{-3}\text{kg}}{4.67 \times 10^{-26}\text{ kg}} = 4.28 \times 10^{22}$ $p = \frac{4.28 \times 10^{22} \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times (22 + 273)\text{ K}}{2.85 \times 10^{-4}\text{ m}^3} = 6.11 \times 10^5\text{ Pa}$ $\Delta p = 6.11 \times 10^5 - 5.75 \times 10^5\text{ Pa} = 3.64 \times 10^4\text{Pa}$		
	Total for question 14		**5**

Question Number	Answer	Mark
15(a)	Energy is transferred from banana to liquid nitrogen **(1)** The molecular potential energy of nitrogen molecules increases (as the nitrogen boils) **Or** This provides the latent heat of vaporisation (of the nitrogen) **Or** This provides the latent heat to change state (of the nitrogen) **(1)**	**2**
15(b)	Use of $\Delta E = mc\Delta\theta$ **(1)** Use of $\Delta E = mL$ **(1)** $m = 0.23$ kg, which is less that 0.5 kg so the teacher's estimate was inaccurate **Or** 9.9×10^4 J > 4.5×10^4 J so the teacher's estimate was inaccurate **(1)** <u>Example of calculation</u> $\Delta E = 0.118 \text{ kg} \times 1.76 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1} \times (292 - 77.4) \text{ K} = 4.46 \times 10^4 \text{ J}$ $m = \dfrac{4.46 \times 10^4 \text{ J}}{1.98 \times 10^5 \text{ J kg}^{-1}} = 0.225 \text{ kg}$	**3**
	Total for question 15	**5**

Question Number	Answer		Mark
16(a)	Calculates surface area of Sun [using $A = 4\pi r^2$]	(1)	
	Use of $L = \sigma A T^4$	(1)	
	Use of $I = \frac{L}{4\pi d^2}$	(1)	
	$I = 0.89\ \mathrm{W\ m^{-2}}$	(1)	4
	<u>Example of calculation</u>		
	$A = 4\pi \times (6.96 \times 10^8\ \mathrm{m})^2 = 6.09 \times 10^{18}\ \mathrm{m}^2$		
	$L = 5.67 \times 10^{-8}\mathrm{W\ m^{-2}K^{-4}} \times 6.09 \times 10^{18}\ \mathrm{m}^2 \times (5800\ \mathrm{K})^4 = 3.91 \times 10^{26}\ \mathrm{W}$		
	$I = \dfrac{3.91 \times 10^{26}\ \mathrm{W}}{4\pi \times (5.91 \times 10^{12}\ \mathrm{m})^2} = 0.891\ \mathrm{W\ m^{-2}}$		
16(b)	**EITHER**		
	Equates $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Use of $\omega = \frac{2\pi}{T}$	(1)	
	Conversion of T to years	(1)	
	$T = 250$ (years)	(1)	
	OR		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Use of $v = \frac{2\pi r}{T}$	(1)	
	Conversion of T to years	(1)	
	$T = 250$ (years)	(1)	4
	<u>Example of calculation</u>		
	$\dfrac{GMm}{r^2} = m\omega^2 r$		
	$\omega = \sqrt{\dfrac{GM}{r^3}} = \sqrt{\dfrac{6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-1}} \times 1.99\ \times 10^{30}\ \mathrm{kg}}{(5.91\ \times\ 10^{12}\ \mathrm{m})^3}}$		
	$\therefore \omega = 8.02 \times 10^{-10}\ \mathrm{rad}\ s^{-1}$		
	$T = \dfrac{2\pi}{\omega} = \dfrac{2\pi\ \mathrm{rad}}{8.02 \times 10^{-10}\ \mathrm{rad\ s^{-1}}} = 7.84 \times 10^9\ \mathrm{s} = \dfrac{7.84 \times 10^9\ \mathrm{s}}{3.15\ \times\ 10^7\ \mathrm{s\ year^{-1}}} = 249\ \mathrm{year}$		
	Total for question 16		**8**

Question Number	Answer		Mark
17(a)	The astronauts must experience a centripetal force as they orbit the Earth **Or** The weight of the astronaut acts as a centripetal force **Or** The astronauts are in free fall as they orbit the Earth They do not experience (normal) contact forces	(1) (1)	2
17(b)	Use of $\Delta F = -k\Delta x$ Use of $T = 2\pi\sqrt{\frac{m}{k}}$ to calculate mass of chair Use of $T = 2\pi\sqrt{\frac{m}{k}}$ to calculate mass of chair plus astronaut Mass difference calculated Mass of astronaut = 67 kg <u>Example of calculation</u> $k = \frac{175\text{ N}}{0.289\text{ m}} = 606\text{ N m}^{-1}$ $m = \frac{kT^2}{4\pi^2} = \frac{606\text{ N m}^{-1} \times (0.858\text{ s})^2}{4\pi^2} = 11.3\text{ kg}$ $m = \frac{606\text{ N m}^{-1} \times (2.26\text{ s})^2}{4\pi^2} = 78.3\text{ kg}$ mass of astronaut $= (78.3 - 11.3)\text{ kg} = 67.0\text{ kg}$	(1) (1) (1) (1) (1)	5
	Total for question 17		**7**

Question Number	Answer		Mark
18(a)	**EITHER** Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $\frac{T_A}{T_B} = 1.76$ Comparison of their ratio with 2 **and** conclusion **OR** Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K T_A = 3410 K **and** T_B = 1932 K Comparison of their value of T_A with $2T_B$ **and** conclusion Example of calculation $\frac{T_A}{T_B} = \frac{\lambda_{max,B}}{\lambda_{max,A}} = \frac{1500 \times 10^{-9}\text{ m}}{850 \times 10^{-9}\text{ m}} = 1.76$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	3
18(b)	Standard candles are stellar objects with a known luminosity Locate a standard candle in the galaxy Measure the intensity of the standard candle (on Earth) Use the inverse square law to calculate the distance to the standard candle **Or** Use $I = \frac{L}{4\pi d^2}$ [I and L must be defined]	**(1)** **(1)** **(1)** **(1)**	4
18(c)	Use of $v = H_0 d$ Use of $t = \frac{1}{H_0}$ Conversion from s to year $t = 1.37 \times 10^{10}$ year Example of calculation $H_0 = \frac{2.02 \times 10^6\text{ m s}^{-1}}{8.70 \times 10^{23}\text{ m}} = 2.32 \times 10^{-18}\text{ s}^{-1}$ $t = \frac{1}{2.32 \times 10^{-18}\text{ s}^{-1}} = 4.31 \times 10^{17}\text{ s}$ $t = \frac{4.31 \times 10^{17}\text{ s}}{3.15 \times 10^{7}\text{ s year}^{-1}} = 1.37 \times 10^{10}$ year	**(1)** **(1)** **(1)** **(1)**	4
	Total for question 18		**11**

Question Number	Answer		Mark
19(a)	A large nucleus splits (into two nuclei plus neutrons) The binding energy increases, (so energy is released) [Accept binding energy per nucleon increases] **Or** There is a decrease in (total) mass, (so energy is released)	**(1)** **(1)**	**2**
19(b)	Binding energy per nucleon read from graph for before and after fission Binding energy before and after fission calculated **Or** Binding energy increase calculated Energy released ≈ 240 (MeV) <u>Example of calculation</u> Increase in binding energy per nucleon = (8.5 – 7.5) MeV = 1.0 MeV Increase in binding energy ≈ 238 × 1.0 MeV Energy released ≈ 240 MeV	**(1)** **(1)** **(1)**	**3**
19(c)(i)	Top line correct Bottom line correct <u>Example of completed equation</u> $^{90}_{38}\mathrm{Sr} \rightarrow {}^{90}_{39}\mathrm{Y} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_e$	**(1)** **(1)**	**2**
19(c)(ii)	Calculates total energy released Conversion between eV and J P = 110 (W) <u>Example of calculation</u> $P = 1295 \times 10^{12}\ \mathrm{s}^{-1} \times 0.546\ \times 10^{6}\mathrm{eV} \times 1.6 \times 10^{-19}\ \mathrm{J\ eV}^{-1} = 113\ \mathrm{W}$	**(1)** **(1)** **(1)**	**3**
19(c)(iii)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ Use of $A = A_0 e^{-\lambda t}$ t = 44 (years) ≠ 50 (years), so claim inaccurate **Or** (After 50 years), A = 1.1 × 10^{15} (Bq) ≠ 1.295 × 10^{15} (Bq) so claim inaccurate **Or** (If A 1.295 × 10^{15} Bq), $A_0 = 4.3 \times 10^{15}$(Bq) ≠ 3.7 × 10^{15} (Bq) so claim inaccurate <u>Example of calculation</u> $\lambda = \frac{\ln 2}{28.8} = 0.0241\ \mathrm{years}^{-1}$ $1295\ \mathrm{TBq} = 3700\ \mathrm{TBq} \times \mathrm{e}^{-0.0241\ \mathrm{years}^{-1} \times t}$ $t = \frac{\ln\left({}^{1295\ \mathrm{TBq}}/_{3700\ \mathrm{TBq}}\right)}{-0.0241\ \mathrm{years}^{-1}} = 43.6\ \mathrm{years}$	**(1)** **(1)** **(1)**	**3**
	Total for question 19		**13**

Question Number	Answer		Mark
20(a)	Alpha radiation would not pass through the sheet of paper	**(1)**	
	No change in count rate when paper placed (between source and GM tube), so there can't be any alpha radiation	**(1)**	
	There can't be any gamma radiation, as gamma radiation would pass through the aluminium sheet **Or** There can't be any gamma radiation, as count rate decreases to background with aluminium sheet.	**(1)**	
	It must be beta radiation as beta radiation would not pass through the aluminium sheet.	**(1)**	**4**
20(b)	**EITHER**		
	Gradient of 1st graph calculated	**(1)**	
	Gradient = (−) μ	**(1)**	
	μ = 60 (cm^{-1})	**(1)**	
	Photon energy read from 2nd graph	**(1)**	
	Photon energy = 70 (keV) which is closest to 80 (keV) so source is ^{133}Xe	**(1)**	
	OR		
	Gradient of 1st graph calculated	**(1)**	
	Gradient = (−) μ	**(1)**	
	μ = 60 (cm^{-1})	**(1)**	
	μ read from 2nd graph for at least one source in table	**(1)**	
	μ for ^{133}Xe = 50 (cm^{-1}), which is closest to 60 (cm^{-1}) so source is ^{133}Xe	**(1)**	**5**
	<u>Example of calculation</u>		
	Gradient $= \dfrac{(60-540)}{8\text{ cm}} = -60\text{ cm}^{-1}$		
	Photon energy = 70 keV		
	Total for question 20		**9**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*21(a)</td><td>
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.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrat throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and line of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructure</td><td>0</td></tr>
</table>

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 There must be a (very) high temperature (in the core)
IC2 To give nuclei/protons large/enough <u>kinetic</u> energy [accept K.E. or E_k]
IC3 So that nuclei/protons get close enough to fuse
IC4 Because there is an electrostatic repulsion between nuclei/protons
IC5 There must be a (very) high density
IC6 To give a high collision rate to maintain fusion
Or To give a high collision rate to maintain high temperature
</td><td>6</td></tr>
</table>

21(b)(i)	Mass difference calculated Energy in MeV Conversion from (M)eV to J B.E./nucleon = 1.12×10^{-12} (J) <u>Example of calculation</u> Mass difference = 3727.6 MeV/c^2 − 2 × 938.28 MeV/c^2 – 2 × 939.57 MeV/c^2 = 28.1 MeV/c^2 Binding energy = 28.1 MeV Binding energy = (28.1×10^6) eV × 1.60×10^{-19} J eV^{-1} = 4.496×10^{-12} J B.E./nucleon = 4.496×10^{-12} J / 4 = 1.124×10^{-12} J	**(1)** **(1)** **(1)** **(1)**	 **4**
21(b)(ii)	**MAX 2** The B.E./nucleon is the energy required to remove a nucleon from the nucleus Large energy is required to break the helium nucleus apart Decay products (of helium) have a lower binding energy per nucleon	 **(1)** **(1)** **(1)**	 **2**
	Total for question 21		**12**

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