Pearson Edexcel

Mark Scheme (Results)

June 2022

Pearson Edexcel International Advanced Level
In Physics (WPH15)
Paper 5: Thermodynamics, Radiation, Oscillations and Cosmology

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Question Paper Log Number: P71881A
Publications Code: WPH15_01_2206_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.

Question Number	Answer	Mark
1	**B is the correct answer** A is not the correct answer, as large values could fit on a linear scale C is not the correct answer, as distance from the star only affects the intensity D is not the correct answer, as the temperature and luminosity scales are independent	**(1)**
2	**C is the correct answer** A is not the correct answer, as $a = (2\pi f)^2 A$ B is not the correct answer, as $E_k = \frac{1}{2}m(2\pi f A)^2$ D is not the correct answer, as $T = \frac{1}{f}$	**(1)**
3	**C is the correct answer** A is not the correct answer, as angular velocity has units (rad) s^{-1} B is not the correct answer, as frequency has units Hz = s^{-1} D is not the correct answer, as rate of decay has units Bq = s^{-1}	**(1)**
4	**B is the correct answer,** as $F = \frac{GMm}{r^2}$	**(1)**
5	**D is the correct answer,** as the temperature must be very high for the nuclei to come close enough for fusion and the density must be very high for the rate of collision of nuclei to be sufficient to sustain fusion.	**(1)**
6	**B is the correct answer,** as $g = \frac{GM}{r^2}$ and $M = \frac{4}{3}\pi\rho r^3$	**(1)**
7	**C is the correct answer,** as the mean momentum of the molecules is zero	**(1)**
8	**C is the correct answer,** as the molecules do not have to be identical	**(1)**
9	**D is the correct answer** A is not the correct answer, as this graph shows *N* decreasing with *t* B is not the correct answer, as this graph shows *N* decreasing with *t* C is not the correct answer, as this graph shows an increasing rate of change of *N*	**(1)**
10	**A is the correct answer,** as the velocity is the gradient of the graph of displacement against time, and the gradient of this graph starts at zero and then becomes negative for the first half cycle.	**(1)**

Question Number	Answer		Mark
11	Use of $L = 14800\ L_{Sun}$	(1)	
	Use of $I = \frac{L}{4\pi d^2}$	(1)	
	$d = 1.1 \times 10^{23}$ m	(1)	**3**
	<u>Example of calculation</u> $L_{candle} = 14\ 800 \times 3.83 \times 10^{26}\ \text{W} = 5.67 \times 10^{30}\ \text{W}$ $d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{5.67 \times 10^{30}\text{W}}{4\pi \times 3.64 \times 10^{-17}\text{W m}^{-2}}} = 1.11 \times 10^{23}\ \text{m}$		
	Total for question 11		**3**

Question Number	Answer		Mark
12(a)(i)	Use of $v = H_0 d$	(1)	
	$H_0 = 2.33 \times 10^{-1}$ (s^{-1})	(1)	**2**
	Example of calculation $H_0 = \frac{72 \times 10^3 \text{m s}^{-1}}{3.09 \times 10^{22} \text{ m}} = 2.33 \times 10^{-18} \text{ s}^{-1}$		
12(a)(ii)	Use of $t = \frac{1}{H_0}$	(1)	
	$t = 1.36 \times 10^{10}$ (years) ecf from (i)	(1)	**2**
	Example of calculation $t = \frac{1}{2.33 \times 10^{-1} \text{ s}^{-1}} = 4.29 \times 10^{17} \text{ s}$ $t = \frac{4.29 \times 10^{17} \text{ s}}{3.16 \times 10^7 \text{ s year}^{-1}} = 1.36 \times 10^{10}$ years		
12(b)	H_0 is halved (for the same recessional velocity)	(1)	
	So the (calculated) age of the universe doubles (dependent upon MP1)	(1)	
	OR		
	The universe would have taken twice as long to expand to its current size (assuming it expanded at the same rate)	(1)	
	So the age of the universe is double what was previously thought (dependent upon MP1)	(1)	**2**
	Allow 1 mark max for H_0 is lower so universe is older than previously thought **Or** universe would have taken longer to expand to current size so it is older than previously thought.		
	Total for question 12		**6**

Question Number	Answer		Mark
13(a)	Top line correct	(1)	
	Bottom line correct	(1)	**2**
	<u>Example of calculation</u> $^{40}_{19}K \rightarrow ^{40}_{20}Ca + ^{0}_{-1}\beta^{-} + ^{0}_{0}\bar{\nu}$		
13(b)	**Any TWO from:**		
	Both have the same mass	(1)	
	Both are leptons	(1)	
	Both are fundamental particles	(1)	
	Both have the same magnitude charge	(1)	
	Both are deflected in electric/magnetic fields	(1)	
	Both are (weakly) ionising	(1)	**2**

13(c)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ (1) Use of $A = A_0 e^{-\lambda t}$ to find time for activity to fall to background level (1) $t = 8.6 \times 10^9$ years, so claim is incorrect (1) **OR** Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ (1) Use of $A = A_0 e^{-\lambda t}$ to find activity after 9×10^9 years (1) $A = 0.33$ Bq so claim is incorrect (1) <u>Example of calculation</u> $\lambda = \frac{\ln 2}{1.25 \times 10^9 \text{ years}} = 5.55 \times 10^{-10} \text{ year}^{-1}$ $\ln\left(\frac{0.42 \text{ Bq}}{48.6 \text{ Bq}}\right) = -5.55 \times 10^{-10} \text{ years}^{-1} \times t$ $\therefore t = \frac{-4.75}{5.55 \times 10^{-10} \text{ years}^{-1}} = 8.56 \times 10^9 \text{ years}$		**3**
	Total for question 13		**7**

Question Number	Answer	Mark
14	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 Striking the glass sets the glass into (free) oscillation.

IC2 Energy is transferred from glass/system and the amplitude (of oscillation) decreases (quickly to zero).
Or the oscillation is damped and the amplitude (of oscillation) decreases (quickly to zero).

IC3 Sliding a wet finger around the top of the glass drives/forces the glass/system into oscillation.

IC4 The driving frequency (produced by the wet finger) is equal/close to the natural frequency (of oscillation) of the glass/system

IC5 Resonance occurs and there is an efficient/maximum transfer of energy

IC6 The amplitude (of oscillation) increases (and transfers energy to the air)

	Total for question 14	**6**

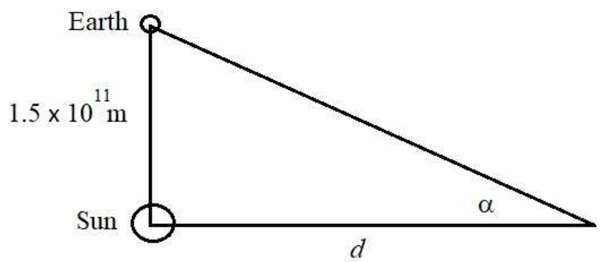
Question Number	Answer	Mark
15(a)(i)	Mass difference calculation (1) Use of $\Delta E = c^2 \Delta m$ (1) $\Delta E = 8.7 \times 10^{-13}$ (J) (1) <u>Example of calculation</u> $\Delta m = (3.48572 - 3.41918 - 0.0664437) \times 10^{-25}$ kg $= 9.63 \times 10^{-30}$kg $\Delta E = (3.00 \times 10^8$ m s$^{-1})^2 \times 9.63 \times 10^{-30}$ kg $= 8.67 \times 10^{-1}$ J	**3**
15(a)(ii)	Use of $E_k = \frac{1}{2}mv^2$ (1) $v = 1.6 \times 10^7$ m s^{-1} (allow ecf from (a)(i)) (1) <u>Example of calculation</u> $0.98 \times 8.67 \times 10^{-1}$ J $= \frac{1}{2} \times 6.64437 \times 10^{-27}$ kg $\times v^2$ $\therefore v = \sqrt{\frac{2 \times 0.98 \times 8.67 \times 10^{-13} \text{ J}}{6.64437 \times 10^{-27} \text{ kg}}} = 1.60 \times 10^7$ m s^{-1}	**2**
15(b)	Momentum must be conserved (in the decay) (1) The lead nucleus must recoil after the decay **Or** the lead nucleus moves in the opposite direction to the alpha particle (1)	**2**
	Total for question 15	**7**

Question Number	Answer	Mark
16(a)(i)	Use of $F = \frac{GMm}{r^2}$ **with** $F = m\omega^2 r$ (1) Re-arrangement with $\omega = \frac{2\pi}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$ (1) Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2) (1) **OR** Use of $F = \frac{GMm}{r^2}$ **with** $F = \frac{mv^2}{r}$ (1) Re-arrangement with $v = \frac{2\pi r}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$ (1) Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2) (1) <u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$ $T^2 = \frac{(2\pi)^2}{GM} r^3$ $\therefore T^2 \propto r^3$	**3**

16(a)(ii)	Use of $T^2 \propto r^3$ (1) T_J = 142 months (11.9 years) (1) Use of $\omega = \frac{\theta}{t}$ and $\omega = \frac{2\pi}{T}$ (1) Calculation of time elapsed for planets to be in opposition (1) Time between opposition is 13.1 months, with an appropriate conclusion (dependent upon MP4) (1) <u>Example of calculation</u> $\left(\frac{T_J}{T_E}\right)^2 = \left(\frac{r_J}{r_E}\right)^3$ $\left(\frac{T_J}{1\text{ year}}\right)^2 = \left(\frac{7.8\times10^{11}\text{ m}}{1.5\times10^{11}\text{ m}}\right)^3$ $T_J = 12\text{ months}\times\sqrt{\left(\frac{7.8\times10^{11}\text{ m}}{1.5\times10^{11}\text{ m}}\right)^3} = 142\text{ months}$ At the next opposition Earth will have done one more orbit than Jupiter plus whatever fraction of an orbit Jupiter has completed. If t is the time to next opposition, both planets will have the same angular displacement, so equating $\theta = 2\pi\, t/T$ for both planets where for Earth the time is (t -12). $\frac{2\pi\text{ rad }(t-12)\text{ month}}{12\text{ month}} = \frac{2\pi\text{ rad }t}{142\text{ month}} \therefore t = 13.1\text{ month}$	5
16(b)	Use of $V = (-)\frac{GM}{r}$ (1) Use of $\Delta V \times m$ (1) $\Delta E_{grav} = 3.3\times10^{34}$ J (1) <u>Example of calculation</u> $\Delta V = -GM\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ $\Delta V = -6.67\times10^{-11}\text{ N m}^2\text{ kg}^{-2}\times2.0\times10^{30}\text{kg}\times\left(\frac{1}{8.2\times10^{11}\text{ m}} - \frac{1}{7.4\times10^{11}\text{ m}}\right)$ $\Delta V = 1.76\times10^7\text{ J kg}^{-1}$ $\therefore \Delta E_{grav} = 1.76\times10^7\text{ J kg}^{-1}\times1.9\times10^{27}\text{ kg} = 3.34\times10^{34}\text{ J}$	3
	Total for question 16	**11**

Question Number	Answer	Mark
17(a)	There is a (resultant) force/acceleration that is: Proportional to the <u>displacement</u> from the equilibrium position (1) and (always) acting towards the equilibrium position (1)	**2**
17(b)(i)	Use of $k = -\frac{\Delta F}{\Delta x}$ (1) k = 4100 (N m^{-1}) (1) <u>Example of calculation</u> $k = -\frac{mg}{\Delta x} = \frac{75\text{ kg} \times 9.81\text{ N kg}^{-1}}{0.18\text{ m}} = 4088\text{ N m}^{-1}$	**2**
17(b)(ii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) Use of $f = \frac{1}{T}$ (1) f = 1.2 Hz (allow ecf from (b)(i)) (1) <u>Example of calculation</u> $T = 2\pi\sqrt{\frac{75\text{ kg}}{4090\text{ N m}^{-1}}} = 0.85\text{ s}$ $f = \frac{1}{0.85\text{ s}} = 1.18\text{ Hz}$	**3**

17(c)	The resultant force on the man = ($mg – R$) where R is the (normal) contact force from the board (1) R decreases as his displacement (from the equilibrium position) increases (1) Man loses contact with board when $R = 0$ **Or** Man loses contact with board when resultant force on man is equal to his weight (1) **OR** Acceleration (for SHM) increases as displacement increases (1) Maximum (downward) acceleration of man is g (1) Man loses contact with board when acceleration of the board is equal to g (1)	**3**
	Total for question 17	**10**

Question Number	Answer		Mark
18(a)(i)	Use of trigonometry to calculate distance **Or** use of small angle approximation to calculate distance	(1)	
	Distance to Wolf 359 = 7.5×10^{16} (m)	(1)	2
	<u>Example of calculation</u>  $\tan(2.01 \times 10^{-6}) = \dfrac{1.50 \times 10^{11}\text{ m}}{d}$ $\therefore d = \dfrac{1.50 \times 10^{11}\text{ m}}{2.01 \times 10^{-6}} = 7.46 \times 10^{16}\text{ m}$		
18(a)(ii)	Parallax angle decreases as distance from the Earth increases **Or** parallax is only suitable for (relatively) close stars	(1)	
	As parallax angle is too small to measure for distant stars	(1)	2
18(b)(i)	λ_{max} read from graph	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	T = 2680 (K) [accept 2635 K → 2760 K]	(1)	3
	<u>Example of calculation</u> $T = \dfrac{2.898 \times 10^{-3}\text{ m K}}{1.08 \times 10^{-6}\text{ m}} = 2683\text{ K}$		
18(b)(ii)	Use of $L = \sigma A T^4$	(1)	
	$L = 4.70 \times 10^{23}$ W (allow ecf from (b)(i))	(1)	
	Comparison of calculated value of L with L_{Sun} and appropriate conclusion **Or** comparison of calculated L/L_{Sun} percentage with 0.1% and appropriate conclusion	(1)	3
	<u>Example of calculation</u> $L = 4\pi\,(0.16 \times 6.96 \times 10^{8}\text{ m})^2 \times 5.67 \times 10^{-8}\text{ W m}^{-2}\text{ K}^{-4}\,(2700\text{ K})^4$ $L = 4.70 \times 10^{23}\ W$ $\dfrac{L}{L_{Sun}} \times 100\% = \dfrac{4.70 \times 10^{23}\ W}{3.83 \times 10^{26}\ W} \times 100\% = 0.12\%$		

Question Number	Answer		Mark
19(a)	Use of $pV = NkT$ Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ $\frac{1}{2}m\langle c^2\rangle = 5.8 \times 10^{-20}$ J <u>Example of calculation</u> $T = \frac{pV}{Nk} = \frac{4.25\times10^{4}\ \text{Pa} \times1.50\times10^{-5}\ \text{m}^3}{1.65\times10^{19} \times1.38\times10^{-23}\ \text{J K}^{-1}} = 2800\ \text{K}$ $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\times 1.38 \times 10^{-23}\ \text{J K}^{-1} \times 2800\ \text{K} = 5.80 \times 10^{-20}\ \text{J}$	(1) (1) (1)	**3**
19(b)	Use of $\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ with wavelength measured on Earth in denominator v = 13500 m s^{-1} The student is correct to say that the star is moving towards the Earth, as the measured wavelength is less than that from the lamp spectrum. Comparison of calculated velocity with 1400 m s^{-1} and appropriate conclusion. <u>Example of calculation</u> $v = \frac{\Delta\lambda}{\lambda}c = \frac{(576.933-576.959)\times10^{-9}\text{m}}{576.959 \times10^{-9}\ \text{m}} \times3.00\times10^{8}\ \text{m s}^{-1} = (-)1.35\times10^{4}\ \text{m s}^{-1}$ So the star's velocity is much larger than 1400 m s^{-1}	(1) (1) (1) (1)	**4**
19(c)	On the main sequence, above the position of the Sun **Or** above and to the left of the position of the Sun	(1)	**1**
	Total for question 18		**8**

Question Number	Answer		Mark
20(a)(i)	Use of appropriate equation of motion $t = 2.9$ (s) Example of calculation $s = ut + \frac{1}{2}at^2$ $\therefore -41.5\text{ m} = 0.5 \times (-9.81\text{ m s}^{-2})\, t^2$ $t = \sqrt{\frac{-41.5\text{ m}}{-0.5 \times 9.81\text{ m s}^{-2}}} = 2.91\text{ s}$	(1) (1)	**2**
20(a)(ii)	Use of $V = \frac{4}{3}\pi r^3$ Use of $\rho = \frac{m}{V}$ Use of $\Delta E = mc\Delta\theta$ Use of $\Delta E = L\Delta m$ Use of $P = \frac{\Delta W}{\Delta t}$ $P = 1.6$ W (allow ecf from (a)(i)) Example of calculation $V = \frac{4}{3}\pi(1.2 \times 10^{-3}\text{ m})^3 = 7.24 \times 10^{-9}\text{ m}^3$ $m = 7.24 \times 10^{-9}\text{ m}^3 \times 1.13 \times 10^4\text{ kg m}^3 = 8.18 \times 10^{-5}\text{ kg}$ $E = 8.18 \times 10^{-5}\text{ kg} \times 130\text{ J kg}^{-1}\text{ K}^{-1} \times (615\text{ K} - 370\text{ K}) = 2.61\text{ J}$ $E = 8.18 \times 10^{-5}\text{ kg} \times 2.47 \times 10^4\text{ J kg}^{-1} = 2.02\text{ J}$ $P = \frac{(2.61\text{ J} + 2.02\text{ J})}{2.9\text{ s}} = 1.60\text{ W}$	(1) (1) (1) (1) (1) (1)	**6**
20(b)(i)	Change in gravitational potential energy of the lead shot and change in internal energy are both proportional to the mass of lead shot **Or** E_k $(= \frac{1}{2}mv^2)$ and $\Delta E = mc\Delta\theta$ both include the same mass **Or** E_{grav} $(= mg\Delta h)$ and $\Delta E = mc\Delta\theta$ both include the same mass So, mass cancels and $\Delta\theta$ is independent of the mass (if no energy is transferred to the surroundings) (dependent upon MP1)	(1) (1)	**2**
20(b)(ii)	Not all the energy will be used to increase the temperature of the lead shot **Or** some energy will be transferred to the surroundings **Or** not all the lead shot will fall through a distance *d* The method will not be accurate, as it will give a value of *c* that is too large **Or** The method will not be accurate as the (measured) temperature change will be too small	(1) (1)	**2**
	Total for question 20		**12**

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