Pearson Edexcel

Mark Scheme (Results)

January 2023

Pearson Edexcel International Advanced Level

In Physics (WPH15/01)

Paper 5: 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** A is not correct, as this will decrease the accuracy C is not correct, as this should not change the accuracy D is not correct, as this will decrease the accuracy	**(1)**
2	**B is the correct answer,** as the mean molecular kinetic energy only depends upon the temperature of the gas.	**(1)**
3	**D is the correct answer** A is not correct, as the magnitude of nuclear B.E is not the least for ^{56}Fe B is not correct, as the magnitude of nuclear B.E. is not the greatest for ^{56}Fe C is not correct, as the magnitude of B.E. per nucleon is the greatest for ^{56}Fe	**(1)**
4	**A is the correct answer,** as $L = \frac{Pt}{m}$	**(1)**
5	**D is the correct answer** A is not correct, as frequency shifts do not allow acceleration to be detected B is not correct, as frequency shifts do not allow acceleration to be detected C is not correct, as frequency would be shifted to lower frequencies for a star moving way from the Earth	**(1)**
6	**A is the correct answer,** as $\Delta m = \frac{\Delta E \times 1.6 \times 10^{-13}\text{ J MeV}^{-1}}{c^2}$	**(1)**
7	**B is the correct answer,** as the intensity half-thickness is 0.4 cm	**(1)**
8	**C is the correct answer,** as there are white dwarf stars but no red giants in the cluster	**(1)**
9	**B is the correct answer** as $v_{\text{max}} = \frac{2\pi x_0}{T}$	**(1)**
10	**B is the correct answer**, as the acceleration time graph is given by the gradient of the velocity time graph, and so the gradient of the velocity graph must start with a zero value and then become positive in the first quarter cycle.	**(1)**

Question Number	Answer		Mark
11(a)	Use of $\rho = \frac{m}{V}$	**(1)**	3
	Use of $\Delta E = mc\Delta\theta$	**(1)**	
	$\Delta E = 1.3 \times 10^{11}$ J	**(1)**	
	[For MP2, must have a temperature difference. Allow a temperature difference with 273 added].		
	<u>Example of calculation</u> $m = 998 \text{ kg m}^3 \times 2750 \text{ m}^3 = 2.74 \times 10^6 \text{ kg}$ $\Delta E = 2.74 \times 10^6 \text{ kg} \times 4190 \text{ J kg}^{-1} \times (28.0 - 16.5)\ ^{\circ}\text{C} = 1.32 \times 10^{11} \text{ J}$		
11(b)	Energy is transferred (from the water) to the surroundings **Or** Not all of the energy from the heater is used to raise the water temperature	**(1)**	1
	[Do not accept vague statements such as "energy is lost" Allow "energy is lost to surroundings" Allow "heat" for "energy"]		
	Total for question 11		**4**

Question Number	Answer		Mark
12(a)	Use $V_{grav} = -\frac{GM}{r}$ to obtain ΔE	(1)	
	Equate ΔE to $\frac{1}{2}mv^2$ **and** re-arrangement to obtain $v = \sqrt{\frac{2GM}{r}}$	(1)	2
	<u>Example of derivation</u> $\Delta E = m \times V_{grav} = \frac{GMm}{r}$ $\frac{1}{2}mv^2 = \frac{GMm}{r}$ $\therefore v^2 = \frac{2GM}{r}$ $\therefore v = \sqrt{\frac{2GM}{r}}$		
12(b)(i)	Use of $v = \sqrt{\frac{2GM}{r}}$	(1)	
	$v = 1.12 \times 10^4$ (m s^{-1})	(1)	2
	<u>Example of calculation</u> $v = \sqrt{\frac{2 \times 6.67 \times 10^{-1}\ \text{N m}^2\ \text{kg}^{-2} \times 5.98 \times 10^{24}\ \text{kg}}{6.36 \times 10^6\ \text{m}}}$ $\therefore v = 1.12 \times 10^4\ \text{m s}^{-1}$		
12(b)(ii)	There is a range of molecular speeds **Or** Some molecules will be travelling (much) faster than 1900 m s^{-1}	(1)	
	So there will be some molecules with a speed greater than the escape velocity **Or** There will be some molecules with enough kinetic energy to escape	(1)	2
	[A correct comparison of the escape velocity (1.1×10^4 m s^{-1}) with $\sqrt{\langle c^2 \rangle}$ (1900 m s^{-1}) scores a maximum of 1 mark.]		
	Total for question 12		**6**

Question Number	Answer		Mark
13	Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ [Must see lab wavelength (393.4 nm) in denominator]	**(1)**	
	Use of $v = H_0 d$ [$d = 5.18 \times 10^{23}$ m]	**(1)**	
	Use of $s = ut$ with $u = c$ **and** $t = 3.15 \times 10^7$ s	**(1)**	
	Conversion of d to light-year **Or** conversion of 55 million light years to m [5.20×10^{23} m]	**(1)**	
	$d = 54.8 \times 10^6$ light-year which is the website value so statement is accurate. **Or** comparison of 5.18×10^{23} m with 5.20×10^{23} m so statement is accurate.	**(1)**	5
	<u>Example of calculation</u> $\frac{(394.5 - 393.4) \times 10^{-9}\ \text{m}}{393.4 \times 10^{-9}\ \text{m}} = \frac{v}{3.0 \times 10^8\ \text{m s}^{-1}}$ $v = 3.0 \times 10^8\ \text{m s}^{-1} \times \frac{1.1 \times 10^{-9}\ \text{m}}{393.4 \times 10^{-9}\ \text{m}} = 8.39 \times 10^5\ \text{m s}^{-1}$ $d = \frac{v}{H_0} = \frac{8.39 \times 10^5\ \text{m s}^{-1}}{1.62 \times 10^{-1}\ \text{s}^{-1}} = 5.18 \times 10^{23}\ \text{m}$ $1\ \text{light year} = 3.0 \times 10^8\ \text{m s}^{-1} \times 3.15 \times 10^7\ \text{s} = 9.45 \times 10^{15}\ \text{m}$ $d = \frac{5.18 \times 10^{23}\ \text{m}}{9.45 \times 10^{15}\ \text{m (light year)}^{-1}} = 5.48 \times 10^7$ light-year $\therefore d \approx 55 \times 10^6$ light-year so website statement is correct		
	Total for question 13		**5**

Question Number	Answer		Mark
14(a)	Horizontal line drawn at 19 mJ	(1)	1
14(b)	Elastic potential energy at 1.0 cm read from graph [accept values in range 4.0 (mJ) – 5.0 (m J)] Use of energy conservation [e.g. kinetic energy = total energy – elastic potential energy] Use of $E_{\mathrm{k}} = \frac{1}{2}mv^2$ v = 0.44 m s^{-1} [A response in which the kinetic energy curve is drawn **and** the value of kinetic energy read off directly can score MP1 and MP2] Example of calculation At 1.0 cm E_{elas} = 4.5 mJ $\therefore E_k = (19 - 4.5) \times 10^{-3}\ \mathrm{J} = 1.45 \times 10^{-2}\ \mathrm{J}$ $1.45 \times 10^{-2}\ \mathrm{J} = \frac{1}{2} \times 0.15\ \mathrm{kg} \times v^2$ $\therefore v = \sqrt{\frac{2 \times 1.45 \times 10^{-2}\ \mathrm{J}}{0.15\ \mathrm{kg}}} = 0.440\ \mathrm{m\ s^{-1}}$	(1) (1) (1) (1)	4
	Total for question 14		**5**

Question Number	Answer	Mark
15(a)	Top line correct **(1)** Bottom line correct **(1)** <u>Example of equation</u> $^{137}_{55}Cs \rightarrow ^{137}_{56}Ba + ^{0}_{-1}\beta^- + ^{0}_{0}\overline{\nu}_e$	**2**
15(b)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ **(1)** Use of $\frac{dN}{dt} = -\lambda N$ **(1)** Use of u = 1.66×10^{-27} kg **(1)** $m = 2.3 \times 10^{-12}$ (kg) **(1)** <u>Example of calculation</u> $\lambda = \frac{\ln 2}{30.2 \times 3.15 \times 10^{7}\ \text{s}} = 7.29 \times 10^{-10}\ \text{s}^{-1}$ $N = \frac{7400\ \text{s}^{-1}}{7.28 \times 10^{-10}\ \text{s}^{-1}} = 1.02 \times 10^{13}$ $m = 1.02 \times 10^{13} \times 137 \times 1.66 \times 10^{-27}\text{kg} = 2.31 \times 10^{-12}$ kg	**4**
	Total for question 15	**6**

Question Number	Answer		Mark
16(a)	Dark matter has mass **Or** Dark matter exerts a gravitational force Dark matter does not emit electromagnetic radiation	**(1)** **(1)**	 **2**
16(b)	Use of $\Delta E = c^2 \Delta m$ Use of 1 eV = 1.6×10^{-19} J $m = 8.5 \times 10^{-19}$ (kg) Example of calculation $m = \frac{4.8 \times 10^8 \text{GeV} \times 1.6 \times 10^{-1} \ \text{J GeV}^{-1}}{(3.0 \times 10^8 \text{ m s}^{-1})^2} = 8.53 \times 10^{-19}$ kg	**(1)** **(1)** **(1)**	 **3**
16(c)	The ultimate fate of the universe depends upon the (average) density of the universe **Or** the (average) density of the universe must be compared with the critical density of the universe The amount of dark matter is uncertain (so the average density is uncertain)	**(1)** **(1)**	 **2**
	Total for question 16		**7**

Question Number	Answer		Mark
17(a)	Use of $pV = NkT$ [Allow temperature substituted in °C] Conversion of temperature to kelvin Use of $\Delta p = p_2 - p_1$ $\Delta p = 1.1 \times 10^6$ Pa [If pressure rounded to 1.4×10^7 Pa, then $\Delta p = 1.2 \times 10^6$ Pa] Example of calculation $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $p_2 = 1.28 \times 10^7 \text{ Pa} \times \frac{(42.5 + 273) \text{ K}}{(17.5 + 273) \text{ K}} = 1.39 \times 10^7 \text{Pa}$ $\Delta p = (1.39 \times 10^7 - 1.28 \times 10^7)\text{Pa} = 1.10 \times 10^6$ Pa	**(1)** **(1)** **(1)** **(1)**	 **4**

Question	Answer	Mark
*17(b)	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 As the temperature increases the (average) kinetic energy of the (air) molecules increases

IC2 So mean/average speed of the air molecules increases
[Accept mean/average velocity/momentum]

IC3 The (average/mean) change of momentum of air molecules when colliding with the tank/walls increases

IC4 The rate of collision of air molecules with the tank/walls increases [Accept "collision frequency" or "number of collisions per second" for "rate of collision"]

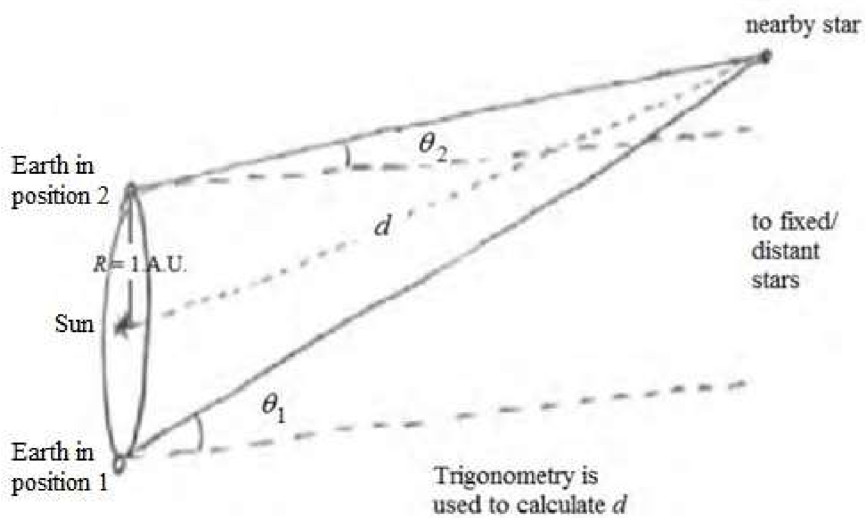
IC5 The rate of change of momentum increases and so the force on the tank/walls, increases

IC6 The pressure (exerted by the gas) increases, since $p = F/A$

[If atoms/particles referred to, then max 1 linkage mark]

6

	Total for question 17	**10**

Question Number	Answer	Mark
18(a)(i)	The star is viewed from two positions at 6 month intervals **Or** the star is viewed from opposite ends of the diameter of the Earth's orbit about the Sun **(1)** The change in angular position of the star against backdrop of distant/fixed stars is measured [Accept "parallax angle" or "angular displacement" for "change in angular position of star"] **(1)** Trigonometry is used to calculate the distance to the star [Do not accept Pythagoras] **(1)** The diameter/radius of the Earth's orbit about the Sun must be known **(1)** Full marks may be obtained from a suitably annotated diagram  [Accept the symmetrical diagram seen in many text books]	**4**
18(a)(ii)	Stars were too far away for changes in angular position to be measured **Or** the parallax angles were too small to be measured [Allow stars are (very) far away and parallax angles are (very) small] **(1)**	**1**
18(b)(i)	A (stellar) object of known luminosity **(1)**	**1**
18(b)(ii)	Identify/locate standard candle (in nearby galaxy) **(1)** Measure intensity of radiation from the standard candle [Do not accept "calculate" for "measure"] **(1)** Use inverse square law to calculate distance [If response refers to $I = \frac{L}{4\pi d^2}$ it must be clear that L is luminosity and I is intensity] **(1)**	**3**
	Total for question 18	**9**

Question Number	Answer		Mark
19(a)	The car (body) is driven/forced into oscillation at its natural frequency **Or** The driving/forcing frequency is the same as the natural frequency of the car (body) **Or** the driving/forcing frequency from the road is the same as the natural frequency (of the car body) There is a maximum transfer of energy (to the car body) [Accept "similar" or "close to" for "the same as" in MP1] [If neither MP is met, MAX 1 mark for a general statement such as " the driving frequency is equal to the natural frequency"]	(1) (1)	2
19(b)	Use of $F = mg$ Use of $\Delta F = (-)k\Delta x$ Use of $T = 2\pi\sqrt{\frac{m}{k}}$ [Allow use of $\omega = \sqrt{\frac{k}{m}}$ **and** $T = \frac{2\pi}{\omega}$] Use of $s = ut$ u = 17 m s^{-1} Example of calculation $k = \frac{65\text{ kg} \times 9.81\text{ N kg}^{-1}}{2.5 \times 10^{-2}\text{ m}} = 2.55 \times 10^4\text{ N m}^{-1}$ $T = 2\pi \times \sqrt{\frac{1365\text{ kg}}{2.55 \times 10^4\text{ N m}^{-1}}} = 1.45\text{ s}$ $u = \frac{25\text{ m}}{1.45\text{ s}} = 17.2\text{ m s}^{-1}$	(1) (1) (1) (1) (1)	5
19(c)	(Kinetic) energy is transferred from the car **Or** (Kinetic energy transferred to the suspension/dampers [Accept "removed" for "transferred"] [Accept reference to "oscillating system"] The energy is dissipated to the surroundings [so the vibration energy decreases]	(1) (1)	2
	Total for question 19		**9**

Question Number	Answer		Mark
20(a)	**EITHER** Use of $r = R_1 + R_2$ [0.165 m] Use of $F = \frac{Gm_1m_2}{r^2}$ Maximum force = 2.83×10^{-7} N [Allow 7.1×10^{-8} N if diameters added] Conclusion consistent with calculated values [e.g. 2.83×10^{-7} (N) < 50×10^{-6} (N) so it can't be measured] **OR** Use of $r = R_1 + R_2$ [0.165 m] Use of $F = \frac{Gm_1m_2}{r^2}$ (Maximum) separation (to give minimum measurable force) = 0.012 m Conclusion consistent with calculated values [e.g. 0.012 (m) < 0.165 (m), so it can't be measured] Example of calculation $r = \sqrt{\frac{6.67 \times 10^{-11}\ \text{N m}^2\text{kg}^{-2} \times 158\ \text{kg} \times 0.73\ \text{kg}}{5.0 \times 10^{-5}\ \text{N}}} = 0.012\ \text{m}$ $r = \left(\frac{0.305\ \text{m}}{2} + \frac{0.025\ \text{m}}{2}\right) = 0.165\ \text{m}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
20(b)(i)	**EITHER** Correct equation re-arranged to make G the subject Base units substituted to obtain required units **OR** Units of G = N m^2 kg^{-2} and N = kg m s^{-2} So units of G = kg m s^{-2} m^2 kg^{-2} = m^3 kg^{-1} s^{-2} Example of derivation $F = G\frac{m_1m_2}{r^2} \therefore G = \frac{Fr^2}{m_1m_2}$ Units of $G = \frac{\text{N m}^2}{\text{kg}^2} = \frac{\text{kg m s}^{-2}\ \text{m}^2}{\text{kg}^2} = \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	**(1)** **(1)** **(1)** **(1)**	**2**
20(b)(ii)	% difference calculated [9.4%] Appropriate comment based on their calculated % difference [One value expressed as a ratio/percentage of the other with an appropriate comment can score MAX 1mark] Example of calculation $\%\ \text{difference} = \frac{(6.67 \times 10^{-11} - 6.04 \times 10^{-11})\ \text{N m}^2\ \text{kg}^{-2}}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}} \times 100\% = 9.4\ \%$	**(1)** **(1)**	**2**
	Total for question 20		**8**

Question Number	Answer		Mark
21(a)(i)	Use of $\lambda_{max}T = 2.898 \times 10^{-3}\text{m K}$ $T = 3570$ (K) <u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3}\text{ m K}}{8.12 \times 10^{-7}\text{ m}} = 3569\text{ K}$	(1) (1)	2
21(a)(ii)	Use of $L = \sigma A T^4$ and $A = 4\pi r^2$ Use of $I = \frac{L}{4\pi d^2}$ Use of intensity of radiation at the Earth Intensity $= 0.42\ I_E$ (ecf from (a)(i)) **Or** 552 (Wm^{-2}) ≈ 583.0 (W m^{-2}) [Using the 'show that' value of T gives $I = 604\ W$ and $I = 0.44\ I_E$] <u>Example of calculation</u> $L = 5.67 \times 10^{-8}\text{ W m}^{-2}\text{ K}^4 \times 4\pi \times (2.03 \times 10^8\text{ m})^2 \times (3570\text{ K})^4$ $\therefore L = 4.76 \times 10^{24}\text{ W}$ $I = \frac{4.76 \times 10^{24}\text{ W}}{4\pi \times (2.55 \times 10^{10}\text{ m})^2} = 583.0\text{ W m}^{-2}$ Intensity $= \frac{583\ W\ m^{-2}}{1380\ W\ m^{-2}} I_E = 0.422\ I_E$ $I = 0.4 \times 1380\text{ Wm}^{-2} = 552\text{ Wm}^{-2}$	(1) (1) (1) (1)	4

21(b)	Use of $V = \frac{4}{3}\pi r^3$ **(1)** Use of $\rho = \frac{m}{V}$ **(1)** Use of $g = \frac{GM}{r^2}$ **(1)** g = 18.4 N kg^{-1} [Intermediate rounding gives g = 18.3 N kg^{-1}] **(1)** Conclusion consistent with calculated value for g compared with 4g **(1)** <u>Example of calculation</u> $V = \frac{4}{3}\pi \times (1.02 \times 10^7)^3 = 4.45 \times 10^{21}\ \text{m}^3$ $m = 6.44 \times 10^3\ \text{kg m}^{-3} \times 4.45 \times 10^{21}\ \text{m}^3 = 2.86 \times 10^{25}\ \text{kg}$ $g = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 2.86 \times 10^{25}\ \text{kg}}{(1.02 \times 10^7\ \text{m})^2} = 18.4\ \text{N kg}^{-1}$ Ratio $= \frac{18.4\ \text{N kg}^{-1}}{9.81\text{N kg}^{-1}} = 1.87$ which is less than 4, so humans could survive the gravitational field strength	**5**
	Total for question 21	**11**

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