Pearson Edexcel

Mark Scheme (Results)

January 2021

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	**D is the correct answer** A is not the correct answer, as the mean velocity of the oxygen molecules and the mean velocity of the nitrogen molecules are both zero. B is not the correct answer, as the mean speed of the oxygen molecules is less than the mean speed of the nitrogen molecules. C is not the correct answer, as the mean kinetic energy of any molecule is determined by the temperature of the gas.	**(1)**
2	**B is the correct answer** A is not the correct answer, as dark matter neither absorbs not emits electromagnetic radiation. C is not the correct answer, as we can detect dark matter as a result of the gravitational force it exerts. D is not the correct answer, as we cannot say what dark matter is.	**(1)**
3	**B is the correct answer** A is not the correct answer, as α-particles are highly ionising. C is not the correct answer, as γ-radiation is weakly ionising. D is not the correct answer, as γ-radiation is very penetrating.	**(1)**
4	**B is the correct answer** A is not the correct answer, as, λmax increases as the metal bar cools. C is not the correct answer, as λmax decreases as the metal bar is heated. D is not the correct answer, as λmax decreases as the metal bar is heated.	**(1)**
5	**C is the correct answer**, as the amplitude of oscillation is proportional to the square root of the energy of the oscillation.	**(1)**
6	**C is the correct answer,** as $I = 1/4\pi d^2$	**(1)**
7	**B is the correct answer** A is not the correct answer, as the weight is only zero at an infinite distance. C is not the correct answer, as this is the weight somewhere between the orbit height and the Earth's surface. D is not the correct answer, as this is the weight at the Earth's surface.	**(1)**
8	**C is the correct answer,** as $L = 4\pi^2\sigma T^4$	**(1)**
9	**A is the correct answer,** as acceleration and displacement must be in antiphase.	**(1)**
10	**C is the correct answer,** as the acceleration graph is equal to the gradient of the velocity graph.	**(1)**

Question Number	Answer		Mark
11	Use of $g = \frac{GM}{r^2}$	(1)	
	$R_\mathrm{m} = 3.4 \times 10^6$ m	(1)	**2**
	<u>Example of calculation</u> $g = \dfrac{GM}{r^2} \therefore r = \sqrt{\dfrac{GM}{g}}$ $\dfrac{R_\mathrm{m}}{R_\mathrm{E}} = \sqrt{\dfrac{M_\mathrm{m}}{M_\mathrm{E}} \times \dfrac{g_\mathrm{E}}{g_\mathrm{m}}}$ $\therefore R_\mathrm{m} = 6.37 \times 10^6\ \mathrm{m} \times \sqrt{\dfrac{1}{9.3} \times 2.6} = 3.37 \times 10^6\ \mathrm{m}$		
	Total for question 11		**2**

Question Number	Answer		Mark
12(a)	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	Use of $\Delta E = mc\Delta\theta$	(1)	
	$t = 216$ (s)	(1)	**(3)**
	<u>Example of calculation</u> $P\,\Delta t = mc\Delta\theta$ $\therefore t = \frac{0.165\text{ kg} \times 4190\text{ J kg}^{-1}\text{ K}^{-1} \times (100 - 12.5)\text{ K}}{280\text{ W}} = 216\text{ s}$		
12(b)	Use of ΔE from (a) **Or** use of $P = \frac{\Delta E}{\Delta t}$ using value for Δt from (a) **Or** use of $\Delta E = mc\Delta\theta$ with $\Delta\theta = (100 - 87.7)$	(1)	
	Use of $\Delta E = mc\Delta\theta$ **and** $\Delta E = mL$	(1)	
	$m = 3.7 \times 10^{-3}$ kg (allow ecf from (a))	(1)	**(3)**
	<u>Example of calculation</u> $P\,\Delta t = mc\Delta\theta + mL$ $280\text{ W} \times 216\,s = 0.165\text{ kg} \times 4190\text{ J kg}^{-1}\text{ K}^{-1} \times (87.7 - 12.5)\text{ K} + m \times 2.29 \times 10^{6}\text{ J kg}^{-1}$ $\therefore 6.05 \times 10^{4}\text{ J} = 5.20 \times 10^{4}\text{ J} + m \times 2.29 \times 10^{6}\text{ J kg}^{-1}$ $\therefore m = \frac{6.05 \times 10^{4}\text{ J} - 5.20 \times 10^{4}\text{ J}}{2.29 \times 10^{6}\text{ J kg}^{-1}} = 3.71 \times 10^{-3}\text{ kg}$		
	Total for Question 12		**6**

Question Number	Answer		Mark
13(a)	$\text{kg m}^2\text{s}^{-2}$	(1)	**(1)**
13(b)(i)	Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ $\ell = 0.99$ m <u>Example of calculation</u> $2.000 \text{ s} = 2\pi\sqrt{\frac{\ell}{9.81 \text{ m s}^{-2}}}$ $\therefore \ell = 9.81 \text{ m s}^{-2} \times \left(\frac{2 \text{ s}}{2\pi}\right)^2 = 0.994$ m	(1) (1)	**(2)**
13(b)(ii)	g varies depending upon location **Or** the metre would depend upon an accurate measurement of time **Or** the metre would depend upon the definition of the second	(1)	**(1)**
	Total for Question 13		**4**

Question Number	Answer		Mark
14(a)	Use of $pV = NkT$ Conversion of temperature to kelvin $p = 5.1 \times 10^5$ Pa <u>Example of calculation</u> $p = \frac{7.5 \times 10^{24} \times 1.38 \times 10^{-23} \text{ J K}^{-1} \times (273 + 20)\text{K}}{6.0 \times 10^{-2} \text{ m}^3} = 5.05 \times 10^5$ Pa	(1) (1) (1)	**(3)**
14(b)	Use of $pV = NkT$ with 288 K Percentage remaining = 91(%) <u>Example of calculation</u> $N = \frac{4.5 \times 10^5 \text{Pa} \times 6.0 \times 10^{-2} \text{ m}^3}{1.38 \times 10^{-23} \text{ J K}^{-1} \times 288 \text{ K}} = 6.79 \times 10^{24}$ Percentage remaining $= \frac{6.8 \times 10^{24}}{7.5 \times 10^{24}} \times 100\ \% = 90.5\ \%$	(1) (1)	**(2)**
	Total for Question 14		**5**

Question Number	Answer		Mark
15	Log expansion of $R = R_0 e^{-\mu x}$ μ identified as (-) gradient Gradient calculated Use of $R = R_0 e^{-\mu x}$ **Or** use $x_{½} = \frac{\ln 2}{\mu}$ Half-value thickness = 1.5 cm Conclusion consistent with half-value thickness **OR** Log expansion of $R = R_0 e^{-\mu x}$ ln R_0 identified as intercept Intercept read from graph R_0/2 calculated and x read from graph Half-value thickness = 1.5 cm Conclusion consistent with half-value thickness <u>Example of calculation</u> $\ln R = \ln R_0 - \mu x$ $\mu = -\left(\frac{5.20 - 6.85}{3.5 \text{ cm}}\right) = 0.471 \text{ cm}^{-1}$ $\frac{R_0}{2} = R_0 e^{-0.471 \text{ cm}^{-1} x}$ $\therefore \ln 2 = 0.471 \text{ cm}^{-1} x$ $\therefore x = 1.47 \text{ cm}$	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	(6)
	Total for Question 15		**6**

Question Number	Answer		Mark
16(a)(i)	Redshift is the (fractional) increase in the wavelength received Due to the source of radiation moving away from the observer [Accept answers in terms of frequency]	(1) (1)	**(2)**
16(a)(ii)	Use of $z = \frac{v}{c}$ Use of $v = H_0\, d$ $d = 2.9 \times 10^{24}$ m <u>Example of calculation</u> $v = 0.0158 \times 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}} = 4.74 \times 10^{6}\ \mathrm{m\ s^{-1}}$ $d = \frac{4.74 \times 10^{6}\ \mathrm{m\ s^{-1}}}{1.62 \times 10^{-18}\ \mathrm{s^{-1}}} = 2.93 \times 10^{24}$ m	(1) (1) (1)	**(3)**
16(b)	The force between the galaxies obeys the inverse square law **Or** $F = \frac{G\, m_1 m_2}{r^2}$ **Or** $F \propto \frac{1}{r^2}$ $F = ma$, so as the (resultant) force increases, so does the acceleration	(1) (1)	**(2)**
	Total for Question 16		**7**

Question Number	Answer		Mark
17(a)(i)	Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ Use of $\omega = \frac{2\pi}{T}$ to calculate T Use of $n = \frac{8.64\times10^4 \text{s}}{T}$ to calculate number of orbits in 1 day In 1 day Salyut 1 would make 16.3 orbits, and so the claim is correct. **OR** Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ Use of $\omega = \frac{2\pi}{T}$ Use of $T = \frac{8.64\times10^4 \text{s}}{16}$ to calculate orbital time if 16 orbits in 1 day 5310 s < 5400 s and so the claim is correct. **OR** Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ Use of $\omega = \frac{2\pi}{T}$ to calculate T Use their value of T to calculate time t for 16 orbits If $t < 8.64 \times 10^4$ s, then claim is correct. Accept use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ for MP1 and use of $v = \frac{2\pi r}{T}$ for MP2. <u>Example of calculation</u> $m\omega^2 r = \frac{GMm}{r^2}$ $\therefore \omega^2 = \frac{GM}{r^3}$ $\therefore \omega = \sqrt{\frac{6.67\times10^{-11}\text{Nm}^2\text{kg}^{-2} \times 5.98\times10^{24}\text{kg}}{(6.37\times10^6\text{m} + 2.11\times10^5\text{ m})^3}}$ $\therefore \omega = 1.183\times10^{-3}$ rad s^{-1} $\therefore T = \frac{2\pi}{\omega} = \frac{2\pi \text{ rad}}{1.183\times10^{-3}\text{ rad s}^{-1}} = 5311$ s Number of orbits = $\frac{8.64\times10^4 \text{ s}}{5310 \text{ s}} = 16.3$ If 16 sunrises per day, $T = \frac{8.64\times10^4 \text{s}}{16} = 5400$ s	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	**(4)**

17(a)(ii)	Use of $V_{grav} = -\frac{GM}{r}$ Recognises that $\Delta E_{\text{grav}} = m \times \Delta V_{\text{grav}}$ $\Delta E_{\text{grav}} = (-)3.7 \times 10^{10}$ J <u>Example of calculation</u> $\Delta V_{\text{grav}} = -\frac{GM}{r_2} + \frac{GM}{r_1}$ $\Delta V_{\text{grav}} = GM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\Delta V_{\text{grav}} = 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 5.98 \times 10^{24}\text{ kg}\left(\frac{1}{6.58 \times 10^6\text{ m}} - \frac{1}{6.37 \times 10^6\text{m}}\right)$ $\therefore \Delta V_{\text{grav}} = -2.00 \times 10^6\text{ J kg}^{-1}$ $\therefore \Delta E_{\text{grav}} = -2.00 \times 10^6\text{ J kg}^{-2} \times 18400\text{ kg} = -3.67 \times 10^{10}\text{ J}$	(1) (1) (1)	**(3)**
17(b)	A (large) drag force acted on the satellite Work is done on satellite (by drag force) and temperature of satellite increases **OR** Air in front of satellite is compressed Energy is transferred to satellite (from hot air) and temperature of satellite increases MP2 dependent upon MP1	(1) (1) (1) (1)	**(2)**
	Total for Question 17		**9**

Question Number	Answer		Mark
18(a)	(For simple harmonic motion the) acceleration is: • (directly) proportional to displacement from equilibrium position • acceleration is in the opposite direction to displacement **Or** (always) acting towards the equilibrium position **OR** (For simple harmonic motion the resultant) force is: • (directly) proportional to displacement from equilibrium position • force is in the opposite direction to displacement **Or** (always) acting towards the equilibrium position	**(1)** **(1)** **(1)** **(1)**	**(2)**
18(b)(i)	Use of $\omega = 2\pi f$ Use of $v = A\omega \sin \omega t$ with $\sin \omega t = 1$ $A = 1.49 \times 10^{-3}$ (m) <u>Example of calculation</u> $\omega = 2\pi \times 240 \text{ Hz} = 1508 \text{ rad s}^{-1}$ $A = \frac{2.25 \text{ m s}^{-1}}{1508 \text{ rad s}^{-1}} = 1.49 \times 10^{-3} \text{ m}$	**(1)** **(1)** **(1)**	**(3)**
18(b)(ii)	Use of $a = -\omega^2 x$ $a = (-)3390 \text{ m s}^{-2}$ (Allow ecf from (b)(i)) <u>Example of calculation</u> $a = -(1508 \text{ rad s}^{-1})^2 \times 1.49 \times 10^{-3} \text{m} = 3388 \text{ m s}^{-2}$	**(1)** **(1)**	**(2)**
18(c)(i)	Material returns to its original shape (and size) once (deforming) force removed	**(1)**	**(1)**
18(c)(ii)	An oscillating system is driven/forced at its natural frequency There is a maximum transfer of energy Resulting in an increasing/maximum amplitude of oscillation	**(1)** **(1)** **(1)**	**(3)**
18(c)(iii)	**Max 2:** The frequency of oscillation of the wings is a multiple of the muscle frequency Impulses are always applied at the same point in the cycle (of the wing's oscillation) So there will still be an efficient transfer of energy from the muscles to the wings [dependent upon either MP1 or MP2]	 **(1)** **(1)** **(1)**	**(2)**
	Total for Question 18		**13**

Question Number	Answer		Mark
19(a)(i)	Top line correct Bottom line correct Example of calculation $^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{20}\mathrm{Ca} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_{e}$	(1) (1)	**(2)**
19(a)(ii)	Calculation of mass difference Conversion from u to kg Use of $\Delta E = c^2 \Delta m$ Use of 1.6×10^{-19} to convert energy to eV $\Delta E = 0.80$ (MeV) Example of calculation: Mass difference = 39.963998 u − 39.962591 u − 0.00054858 u = 8.584×10^{-4} u Mass difference = 8.584×10^{-4} u × 1.66×10^{-27} kg u^{-1} = 1.425×10^{-30} kg $\Delta E = c^2 \Delta m = (3.00 \times 10^{8}\ \mathrm{m\ s^{-1}})^2 \times 1.425 \times 10^{-30}\ \mathrm{kg} = 1.282 \times 10^{-13}\ \mathrm{J}$ $\Delta E = \dfrac{1.282 \times 10^{-13}\ \mathrm{J}}{1.60 \times 10^{-13}\ \mathrm{J\ MeV^{-1}}} = 0.802\ \mathrm{MeV}$	(1) (1) (1) (1) (1)	**(5)**
19(a)(iii)	Momentum/KE is given to 3 particles in the decay **Or** (KE of Ca is negligible so) KE for the beta-neutrino pair was constant The energy split between the beta particle and the neutrino is random **Or** the momentum of the emitted beta particle varies **Or** The (anti) neutrino energy varies	(1) (1)	**(2)**

19(b)(i)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ (1) Use of $\frac{\Delta N}{\Delta t} = (-)\lambda N$ (1) $A = 1.94 \times 10^5$ (Bq) (1) <u>Example of calculation:</u> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{1.25 \times 10^9 \times 3.15 \times 10^7 \text{s}} = 1.76 \times 10^{-17}\ \text{s}^{-1}$ $\frac{\Delta N}{\Delta t} = \lambda N = 1.76 \times 10^{-17}\ \text{s}^{-1} \times 1.10 \times 10^{22} = 1.94 \times 10^5\ \text{Bq}$		**(3)**
19(b)(ii)	Use of $A = A_0 e^{-\lambda t}$ (1) $t = 8.6 \times 10^7$ years, so claim is false. **Or** Activity after 50 years = 1.94×10^5 Bq so claim is false (valid calculation needed) (1) (ecf activity from (i)) <u>Example of calculation</u> $1.85 \times 10^5 = 1.94 \times 10^5 e^{-1.76\times10^{-17}\,t}$ $-1.76 \times 10^{-17}\ \text{s}^{-1} \times t = \ln\left(\frac{1.85 \times 10^5\ \text{Bq}}{1.94 \times 10^5\ \text{Bq}}\right)$ $t = \frac{-0.0475}{-1.76\times10^{-17}} = 2.70 \times 10^{15}\ \text{s} = 8.57\times10^7$ years		**(2)**
	Total for question 19		**14**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>20(a)</td><td>Star on main sequence with a relative luminosity of 1 (1)</td><td>(1)</td></tr>
<tr><td>*20(a)(ii)</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><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</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 When hydrogen fusion ends main sequence stars evolve into red giant stars
IC2 This happens first for stars near the top of the main sequence
Or this happens first for the (most) massive main sequence stars
IC3 Red giant stars are located above the main sequence
IC4 When helium fusion ends red giant stars evolve into white dwarf stars
IC5 White dwarf stars are located below the main sequence
IC6 Red giant stars are larger (in surface area) and have a lower (surface) temperature
Or White dwarf stars are smaller (in surface area) and have a higher (surface) temperature
</td><td>(6)</td></tr>
</table>

20(b)(i)	λ value read from graph Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ for either spectral line $v = (-)3.05 \times 10^5$ m s^{-1} Andromeda is moving towards the Earth <u>Example of calculation</u> $\frac{393.0 \text{ nm} - 393.4 \text{ nm}}{393.4 \text{ nm}} = \frac{v}{3.00 \times 10^8 \text{ m s}^{-1}}$ $\therefore v = 3.00 \times 10^8 \text{m s}^{-1} \times \left(\frac{-0.4 \text{ nm}}{393.4 \text{ nm}}\right) = -3.05 \times 10^5 \text{ m s}^{-1}$	(1) (1) (1) (1)	**(4)**
20(b)(ii)	A layer of dust around the candle would reduce the intensity Intensity obeys an inverse square law **Or** $I = \frac{L}{4\pi d^2}$ (symbol *I* **or** *L* defined) A smaller value of intensity would lead to larger (calculated) distance, so claim is valid	(1) (1) (1)	**(3)**
	Total for question 20		**14**