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Pearson Edexcel

Mark Scheme (Results)

Summer 2023

Pearson Edexcel International

Advanced Level in Physics (WPH15)

Paper 1

Unit 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.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. **It is not a set of model answers.**

1. Mark scheme format

1.1 You will not see 'wtte' (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. '<u>resonance</u>'

1.2 Bold lower case will be used for emphasis e.g. '**and**' when two pieces of information are needed for 1 mark.

1.3 Round brackets ( ) indicate words that are not essential e.g. "(hence) distance is increased".

1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.

2.2 This does not apply in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

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2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.
2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.
2.5 The mark scheme will indicate if no unit error is to be applied by placing brackets around the unit.

3. Significant figures
3.1 Use of too many significant figures in the theory questions will not prevent a mark being awarded if the answer given rounds to the answer in the MS.
3.2 Too few significant figures will mean that the final mark cannot be awarded in 'show that' questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.
3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.
3.4 The use of g = 10 m s^{-2} or 10 N kg^{-1} instead of 9.81 m s^{-2} or 9.81 N kg^{-1} will be penalised by one mark (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}
3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations
4.1 **use of** the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.
4.2 If a 'show that' question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.
4.3 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Expression
5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.
5.2 Marks are awarded for indicative content and for how the answer is structured.
5.3 Linkage between ideas, and fully-sustained reasoning is expected.

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Question Number	Answer	Mark
1	**B is the correct answer** A is not correct, as this would lead to a flet universe C is not correct, as density values (and not mass values) must be compared D is not correct, as density values (and not mass values) must be compared	**(1)**
2	**C is the correct answer,** as $\lambda_{\text{observed}} = \lambda + 0.025\lambda$	**(1)**
3	**C is the correct answer,** as (distance to star) $= \frac{1}{\text{(parallax angle)}}$	**(1)**
4	**B is the correct answer,** as $\Delta(PE)_{\text{grav}} = -\frac{GMm}{r_{\text{final}}} - \left(-\frac{GMm}{r_{initial}}\right)$	**(1)**
5	**B is the correct answer,** as $v = H_0 d$	**(1)**
6	**B is the correct answer** A is not correct, as this describes an elastic material C is not correct, as this describes a strong material D is not correct, as this describes a stiff material	**(1)**
7	**C is the correct answer** A is not correct, as the longer the count time the larger the count B is not correct, as background count rate varies from place to place D is not correct, as different detectors have different sensitivities	**(1)**
8	**C is the correct answer,** as $g_{\text{Mars}} = \frac{M_{\text{Mars}}}{M_{\text{moon}}} \times \frac{r^2_{\text{moon}}}{r^2_{\text{Mars}}} \times g_{\text{moon}}$	**(1)**
9	**C is the correct answer** A is not correct, as the pressure, volume and temperature of each gas is the same B is not correct, as the temperature of each gas is the same D is not correct, as the temperature and the number of molecules is the same for each gas	**(1)**
10	**B is the correct answer,** as the gradient of the velocity-time graph gives the displacement time graph	**(1)**

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Question Number	Answer	Mark
11(a)	Top line correct **(1)** Bottom line correct **(1)** Example of calculation $^{187}_{75}\text{Re} \rightarrow {}^{187}_{76}\text{Os} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}$	**2**
11(b)	Use of 1 eV = 1.6×10^{-19} J [4.16×10^{-16}] **(1)** Use of $E_k = \frac{1}{2}mv^2$ [Allow use of the mass of an proton] **(1)** $v = 3.0 \times 10^7$ m s^{-1} **(1)** Example of calculation $2.6 \times 10^3 \times 1.6 \times 10^{-19}\text{ J} = \frac{1}{2} \times 9.11 \times 10^{-31}\text{ kg} \times v^2$ $\therefore v = \sqrt{\frac{2 \times 4.16 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 3.02 \times 10^7\text{ m s}^{-1}$	**3**
	Total for question 11	**5**

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Question Number	Answer	Mark
12(a)	Use of $pV = NkT$ **(1)** Conversion of temperature to kelvin **(1)** $N = 2.1 \times 10^{24}$ [min 2sf] **(1)** [Correct answer from use of $pV=nRT$ gets full marks, otherwise only MP2 available] <u>Example of derivation</u> $N = \frac{1.24 \times 10^5 \text{ Pa} \times 7.08 \times 10^{-2} \text{ m}^3}{1.38 \times 10^{-23} \text{ J K}^{-1} \times (273 + 25) \text{ K}} = 2.13 \times 10^{24}$	3
12(b)	Use of $pV = NkT$ **(1)** $\Delta N = 1.5 \times 10^{24}$ (allow ecf from (a)) **(1)** <u>Example of calculation</u> $\frac{p_2}{p_1} = \frac{N_2}{N_1}$ $N_2 = 2.13 \times 10^{24} \times \left(\frac{3.45 \times 10^4 \text{ Pa}}{1.24 \times 10^5 \text{ Pa}}\right) = 5.93 \times 10^{23}$ $\Delta N = 2.13 \times 10^{24} - 5.93 \times 10^{23} = 1.54 \times 10^{24}$ [Use of 'Show that' value from (a) gives $\Delta N = 1.44 \times 10^{24}$]	2
	Total for question 12	**5**

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Question Number	Answer	Mark
13	The thickness of the track related to the ionising ability of the particle (not its mass) **(1)** Alpha is strongly ionising **and** beta is only moderately ionising (so alpha tracks are thick and beta tracks are thin) **(1)** [Allow a comparison of ionising power of alpha with that of beta] The shape of the track related to the mass of the particle (not its ionising ability) **(1)** Alpha particles are massive particles **and** beta particles are not massive particles (so alpha tracks are straight and beta tracks are twisted) **(1)** [Allow a comparison of alpha mass with beta mass]	**4**
	Total for question 13	**4**

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Question Number	Answer		Mark
14(a)	Determine V using given dimensions	(1)	
	Use of $\rho = \frac{m}{V}$	(1)	
	$m = 0.022$ (kg) [min 2sf]	(1)	3
	Example of calculation $V = (2.5 \times 10^{-2}\text{m})^2 \times 3.5 \times 10^{-2}\text{m} = 2.19 \times 10^{-5}\text{ m}^3$ $1.00 \times 10^3 \text{kg m}^{-3} = \frac{m}{2.19 \times 10^{-5}\text{ m}^3}$ $\therefore m = 0.0219$ kg		
14(b)	Use of $\Delta E = mc\Delta\theta$	(1)	
	Use of $\Delta E = mL$	(1)	
	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	P = 79 W so not 110 W [Use of show that value for *m* gives 71 W] (allow ecf from (a)) **Or** t = 8.5 min not 12 mins so the energy is not transferred at a rate of 110 W [Use of show that value for *m* gives 7.8 min (467 s)] (allow ecf from (a)) **Or** $\Delta E = 7.92 \times 10^4$J not 5.65×10^4 J so the energy is not transferred at a rate of 110 W [Use of show that value for m gives 4.06×10^4 J] (allow ecf from (a))	(1)	4
	Example of calculation $\Delta E = 6 \times 0.022 \text{ kg} \times 4180 \text{ J kg}^{-1}\text{ K}^{-1} \times 22.5 \text{ K} = 1.24 \times 10^4 \text{ J}$ $\Delta E = 6 \times 0.022 \text{ kg} \times 3.34 \times 10^5 \text{ J kg}^{-1} = 4.41 \times 10^4 \text{ J}$ $P = \frac{(1.24 \times 10^4 + 4.41 \times 10^4)\text{J}}{(12 \times 60)\text{ s}} = \frac{5.65 \times 10^4}{720} = 78.5 \text{ W}$ **Or** $t = \frac{(1.24 \times 10^4 + 4.41 \times 10^4)\text{J}}{110 \text{ W}} = 514 \text{ s} = 8.5 \text{ min}$ **Or** $\Delta E = 110 \text{ W} \times (12 \times 60)\text{s} = 7.92 \times 10^4\text{J}$		
	Total for question 14		7

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Question Number	Answer		Mark
15(a)	Conversion of beats minute^{-1} to Hz [Accept calculation of T]	(1)	
	Use of $\omega = 2\pi f$	(1)	
	Use of $v = -A\omega \sin \omega t$ with $\sin \omega t = 1$	(1)	
	A = 1.5 (mm) [Allow max displacement = 2A]	(1)	4
	Example of calculation $f = \frac{142}{60\text{ s}} = 2.37\text{ Hz}$ $\omega = 2\pi \times 2.37\text{ s}^{-1} = 14.9\text{ rad s}^{-1}$ $A = \frac{22.0 \times 10^{-3}\text{ m s}^{-1}}{14.9\text{ s}^{-1}} = 1.48 \times 10^{-3}\text{ m} = 1.48\text{ mm}$		
15(b)	For an object to move with simple harmonic motion there must be an acceleration/(resultant) force that is proportional to the displacement from the equilibrium position	(1)	
	and (always) acting towards the equilibrium position	(1)	2
	(For equilibrium position accept: undisplaced point/position or fixed point/position or central point/position) [MP2 Accept acceleration/force is in the opposite direction to the displacement] [An attempt to use the equation can only score if all terms are defined and the minus sign explained]		
	Total for question 15		**6**

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Question Number	Answer		Mark
16(a)	Calculation of mass difference	(1)	
	Use of 1 u = 1.66×10^{-27} kg	(1)	
	Use of $\Delta E = c^2 \Delta m$	(1)	
	$\Delta E = 7.6 \times 10^{-13}$ (J)	(1)	4
	<u>Example of calculation</u> $\Delta m = (230.0331 - 226.0254 - 4.0026)\ \text{u} = 5.1 \times 10^{-3}\ \text{u}$ $\Delta m = 5.1 \times 10^{-3} \times 1.66 \times 10^{-27}\ \text{kg} = 8.47 \times 10^{-30}\ \text{kg}$ $\Delta E = (3.00 \times 10^{8}\ \text{m s}^{-1})^2 \times 8.47 \times 10^{-30}\ \text{kg} = 7.62 \times 10^{-13}\ \text{J}$ [Use of 1 u = 1.67×10^{-27} kg gives $\Delta E = 7.67 \times 10^{-13}$ J] [Use of 931.5 MeV factor scores full marks if final answer correct, otherwise MP1 is only mark that may be awarded]		
16(b)	Use of $\lambda = \frac{\ln 2}{t_{½}}$	(1)	
	Use of $N = N_0 e^{-\lambda t}$	(1)	
	Use of 90% $[\frac{N}{N_0} = 0.1]$	(1)	
	$t = 2.5 \times 10^{5}$ (years)	(1)	4
	<u>Example of calculation</u> $\lambda = \frac{\ln 2}{t_{½}} = \frac{0.693}{75400\ \text{years}} = 9.19 \times 10^{-6}\ \text{year}^{-1}$ $0.1 = e^{-9.19 \times 10^{-6}\, t}$ $t = \frac{\ln 0.1}{-9.19 \times 10^{-6}\ \text{year}^{-1}} = 2.51 \times 10^{5}\ \text{years}$ [Calculation of the time taken for 90% to remain gives $t = 1.15 \times 10^{4}$ years]		
	Total for question 16		**8**

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Question Number	Answer	Mark
17(a)	In the fusion process mass decreases **(1)** So energy is released according to $\Delta E = c^2 \Delta m$ **Or** energy is released to conserve mass-energy **Or** binding energy per nucleon increases **(1)**	**2**
17(b)	**Max 4** Very high temperature so that the nuclei have sufficient kinetic energy **(1)** Nuclei must overcome electrostatic repulsion/forces **(1)** [Allow a reference to overcome repulsion/forces due to positively charged nuclei] So that the nuclei come close enough to fuse **(1)** Sufficient density so that the collision rate (between nuclei) is high (enough) **(1)** Sufficient collision rate to maintain the (very high) temperature **(1)**	**4**
17(c)	Values of B.E./nucleon read from graph [min 2 values] **(1)** Calculation of binding energies **(1)** Energy released = 17.4 (MeV) [Allow 17.3 MeV – 17.5 MeV] **(1)** <u>Example of calculation</u> B.E./nucleon of ^{2}H = 1.1 MeV B.E./nucleon of ^{3}H = 2.8 MeV B.E./nucleon of 4He = 7.0 MeV So energy released = 4 × 7.0 MeV – (2 × 1.1 MeV + 3 × 2.8 MeV) = 17.4 MeV	**3**
	Total for question 17	**9**

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Question Number	Answer	Mark
*18	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 internal energy of the wax decreases during cooling
Or The internal energy of the wax decreases as time passes

IC2 The internal energy of the wax is the sum of potential energy and kinetic energy of the molecules

IC3 As the <u>temperature</u> of the wax decreases, the (molecular) kinetic energy decreases

IC4 Between times X and Y the (liquid wax is solidifying and the molecular) potential energy decreases

IC5 Between times X and Y the <u>temperature</u> is constant and so there is no change in (molecular) kinetic energy

IC6 At time Y the wax has solidified

Mark: **6**

	Total for question 18	**6**

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Question Number	Answer		Mark
19(a)	Use of $T = \frac{t_{\text{mean}}}{30}$ [t_{mean} = 13.675 s]	(1)	4
	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ [Allow use of $\omega^2 = \frac{k}{m}$ with $T = \frac{2\pi}{\omega}$]	(1)	
	Use of factor of 2 applied to either *m* or *k*	(1)	
	k = 20.9 (N m^{-1}), so label is correct.	(1)	
	<u>Example of calculation</u> $T = \frac{(13.65 + 13.70)/2}{30} = 0.456\text{ s}$ $0.456\text{ s} = 2\pi\sqrt{\frac{0.22\text{ kg}}{k}}$ $\therefore k = \frac{4\pi^2 \times 0.22\text{ kg}}{(0.456\text{ s})^2} = 41.8\text{ N m}^{-1}$ $k = \frac{41.8\text{ N m}^{-1}}{2} = 20.9\text{ N m}^{-1}$		
19(b)(i)	When the driving frequency is equal to the natural frequency of the mass-spring system	(1)	3
	Resonance occurs	(1)	
	There is a maximum transfer of energy (to the mass-spring system and the amplitude increases)	(1)	
	[Allow spring for mass-spring system]		
19(b)(ii)	Some of the energy from the student's hand is transferred to the oscillating mass **and** some of the energy is transferred to surroundings	(1)	3
	When the amplitude is a maximum, minimum energy is transferred to surroundings [Accept "at the natural frequency" or "resonance" for when the amplitude is a maximum]	(1)	
	. (In a closed system) total energy is constant so the student is incorrect. **Or** She is incorrect as energy is always conserved (in a closed system)	(1)	
	Total for question 19		**10**

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Question Number	Answer	Mark
20(a)	Reverse scale **(1)** Approximately logarithmic values **(1)** [With realistic values of temperature. Max temperature range 50000 – 2000 K, with temperature of Sun about 6000 K]	**2**
20(b)	(This star cluster is not a young star cluster because) This cluster has red giant stars on the top right of the diagram **(1)** And white dwarf stars bottom left of diagram **(1)** A young cluster would only have a main sequence **(1)** **Or** Red giant stars only occur in the later stages of a star's evolution **Or** White dwarf stars only occur in the later stages of a star's evolution If no marks can be awarded, award max 1 for: The cluster has red giant stars **and** white dwarf stars [Accept positions of red giant stars and white dwarf stars shown on the diagram]	**3**
20(c)	The luminosity of the standard candle is known **(1)** Measure/determine intensity of radiation from V1 [standard candle] **(1)** [do not accept 'calculate'] Use inverse square law to calculate distance (to cluster) **Or** use $I = \frac{L}{4\pi d^2}$ to determine distance, where I is intensity **and** L is luminosity **(1)** Distance is too large (for V1 to be in a nearby cluster) [Must have the idea of being too far away, rather than just being far away] **(1)**	**4**
	Total for question 20	**9**

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Question Number	Answer		Mark
21(a)(i)	λ_{max} read from graph	(1)	
	Use of $T = \frac{2.898 \times 10^{-3}\text{ m K}}{\lambda_{max}}$	(1)	
	T = 3400 (K) (accept 3350K – 3450K) [min 2 sf]	(1)	3
	Example of calculation λ_{max} = 850 nm $T = \frac{2.898 \times 10^{-3}\text{ m K}}{850 \times 10^{-9}\text{ m}} = 3410\text{ K}$		
21(a)(ii)	Use of $A = 4\pi r^2$	(1)	
	Use of $L = \sigma A T^4$	(1)	
	Use of $L_{Sun} = 3.83 \times 10^{26}$ W	(1)	
	$\frac{L}{L_{Sun}} = 0.35\%$ (allow ecf from(a)(i))	(1)	
	Calculated value of ratio compared with 0.5% and conclusion made	(1)	
	Or		
	Use of $A = 4\pi r^2$	(1)	
	Use of $L = \sigma A T^4$	(1)	
	Use of $L_{Sun} = 3.83 \times 10^{26}$ W	(1)	
	$L_{Ross} = 1.34 \times 10^{24}$ W **and** 0.5% $L_{Sun} = 1.92 \times 10^{24}$ W	(1)	
	Calculated values of L_{Ross} and 0.5% L_{Sun} compared and conclusion made	(1)	5
	[Use of show that value of T gives $L_{Ross} = 8.04 \times 10^{23}\text{ W m}^{-2}$ Use of show that value gives ratio = 0.0021]		
	Example of calculation $L = 4\pi(1.18 \times 10^8)^2 \times 5.67 \times 10^{-8}\text{ W m}^{-2}\text{ K}^{-4} \times (3400)^4 = 1.33 \times 10^{24}\text{ W m}^{-2}$ $\frac{L}{L_{Sun}} = \frac{1.33 \times 10^{24}\text{ W}}{3.83 \times 10^{26}\text{ W}} = 0.00346$ $\therefore L = 0.35\%$ of L_{Sun} which is less than 0.5%, so statement is correct		

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21(b)	Equate $F = \frac{GMm}{r^2}$ and $F = m\omega^2 r$ Use of $\omega = \frac{2\pi}{T}$ $T = 2.29 \times 10^6$ s **OR** Use of $F = \frac{GMm}{r^2}$ **with** $F = \frac{mv^2}{r}$ Use of $v = \frac{2\pi r}{T}$ $T = 2.29 \times 10^6$ s [Full credit for a correct answer from use of memorised relationship between T^2 and r^3, incorrect answer scores 0 unless equation is derived and values substituted] <u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $\therefore \omega = \sqrt{\frac{GM}{r^3}} = \sqrt{\frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 3.38 \times 10^{29}\ \text{kg}}{(0.096 \times 1.50 \times 10^{11}\ \text{m})^3}} = 2.75 \times 10^{-6}\ \text{rad s}^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi}{2.75 \times 10^{-6}\ \text{s}^{-1}} = 2.29 \times 10^6\ \text{s}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **3**
	Total for question 21		**11**

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