Mark Scheme (Results)

October 2022

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.

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.

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 means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be 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 mean that one mark will not be awarded (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 in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 Bald (i.e. no working shown) correct answers may score full marks.

4.2 Some working is expected for full marks to be scored in a 'show that' question or an extended calculation question.

4.3 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.

4.4 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.

4.5 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.

Question Number	Answer	Mark
1	**B is the correct answer** A is not the correct answer, as fission produces radioactive isotopes. C is not the correct answer, as a very high temperature is only required for fusion. D is not the correct answer, as only fission occurs spontaneously.	**(1)**
2	**B is the only correct answer** A is not the correct answer, as for volume to be proportional to temperature, the temperature must be measured in kelvin. C is not the correct answer, as the law only applies to a fixed mass of gas. D is not the correct answer, as the volume occupied by the gas must stay constant	**(1)**
3	**C is the correct answer** A is not the correct answer, as alpha radiation would be stopped by a sheet of paper B is not the correct answer, as some gamma radiation would penetrate the lead sheet. D is not the correct answer, as some gamma radiation would penetrate the lead sheet.	**(1)**
4	**D is the correct answer** A is not the correct answer, as the temperature scale must be a reverse logarithmic scale B is not the correct answer, as the temperature scale must be a reverse scale C is not the correct answer, as the temperature scale must be a logarithmic scale	**(1)**
5	**D is the correct answer,** A is not the correct answer, as each decay path is defined. B is not the correct answer, as half of the unstable nuclei have decayed after a half-life. C is not the correct answer, as this is a definition of spontaneous decay.	**(1)**
6	**D is the correct answer,** as $z = \left(\frac{H_0}{c}\right) d$, so $H_0 = (\text{gradient}) \times c$	**(1)**
7	**A is the correct answer,** as $\Delta E_{\text{grav}} = -GMm\left(\frac{1}{R} - \frac{1}{2R}\right)$	**(1)**
8	**C is the correct answer,** as $l = \frac{T^2 g}{4\pi^2}$	**(1)**
9	**C is the correct answer,** as $I = \frac{L}{4\pi d^2}$, so $\frac{L_C}{L_S} = \frac{I_C \times d_C^2}{I_S \times d_S^2} = \frac{I_C}{I_S} \times \frac{d_C^2}{d_S^2}$	**(1)**
10	**D is the correct answer.** as both the amplitude and the natural frequency increase	**(1)**

Question Number	Answer	Mark
11	Use of $\Delta E = mc\Delta\theta$ **(1)** Use of volume flow rate to calculate V **(1)** Use of $\rho = \frac{m}{V}$ to calculate mass of shower water **(1)** Use of $\frac{\text{Energy used to heat bathwater}}{\text{Energy used to heat shower water}}$ **Or** calculates 10 × (energy used to heat shower water) **(1)** Taking a bath uses 12 times as much energy **Or** $1.14 \times 10^7 \text{J} > 9.34 \times 10^6$ J so bath uses more than 10 × shower energy **(1)** <u>Example of calculation</u> $\Delta E = 160 \text{ kg} \times 4180 \text{ J kg}^{-1}\text{K}^{-1} \times (32 - 15)\text{K} = 1.14 \times 10^7 \text{J}$ In 1 second, $m = 1.00 \times 10^3 \text{ kg m}^{-3} \times 1.8 \times 10^{-5} \text{ m}^3 = 0.018 \text{ kg}$ $m = 0.018 \text{ kg s}^{-1} \times 9 \times 60 \text{ s} = 9.72 \text{ kg}$ $\Delta E = 9.72 \text{ kg} \times 4180 \text{ J kg}^{-1} \text{ K}^{-1} \times (38 - 15) \text{ K} = 9.34 \times 10^5 \text{ J}$ $\text{Energy ratio} = \frac{1.14 \times 10^7 \text{J}}{9.34 \times 10^5 \text{J}} = 12.2$	5
	Total for question 11	**5**

Question Number	Answer		Mark
12	Use of $pV = NkT$ [must see substitution of values of p, k and T]	**(1)**	
	Conversion of temperature to kelvin	**(1)**	
	Use of $\rho = \frac{m}{V}$ [allow substitution of mass of one molecule]	**(1)**	
	Use of $m = N \times$ mass of a molecule	**(1)**	
	$\rho = 180 \text{ kg m}^{-3}$	**(1)**	**5**
	<u>Example of calculation</u> $\rho = \frac{N \times 5.3 \times 10^{-26}\text{ kg}}{V} = \frac{p \times 5.3 \times 10^{-26}\text{ kg}}{kT}$ $\therefore \rho = \frac{1.4 \times 10^{7}\text{Pa} \times 5.3 \times 10^{-26}\text{ kg}}{1.38 \times 10^{-23}\text{m}^2\text{ kg s}^{-2}\text{ K}^{-1} \times (273 + 25)\text{K}} = 180.4 \text{ kg m}^{-3}$		
	Total for question 12		**5**

Question Number	Answer	Mark
*13	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 Use (stellar) parallax to determine distance to a nearby standard candle,

IC2 Measure the intensity of radiation from the standard candle
Or Measure λ_{max} and use Wien's law to determine the (surface) temperature of the standard candle

IC3 Use inverse square law to calculate the luminosity of the standard candle
Or Use the Hertzsprung-Russell diagram to determine the luminosity of the standard candle

IC4 Locate standard candle (in nearby galaxy)

IC5 Standard candle has a known luminosity

IC6 Measure intensity of radiation from the standard candle and use inverse square law to calculate distance to nearby galaxy

6

	Alternative for IC1, IC2 and IC3: IC1 Identify/observe a (Cepheid) variable star IC2 Measure the period/frequency of intensity variation IC3 Use a known relationship between period and luminosity to calculate the luminosity of the star	
	Total for question 13	**6**

Question Number	Answer	Mark
14(a)	Determines period from at least 2 cycles [to within 1 square] **(1)** Converts period into hours **(1)** T = 12.0 → 13.0 (hours) **(1)** Example of calculation $13T = (6.9 - 0.2) \times 24$ hours = 160.8 hours $T = \frac{160.8 \text{ hours}}{13} = 12.4$ hours	**3**
14(b)	Period of the tide matches natural period of oscillation of water in the bay [accept references to frequency] **(1)** Efficient/maximum transfer of energy (into water in the bay) **Or** Resonance occurs **(1)** Amplitude (of tide) increases **Or** There is a maximum amplitude **(1)**	**3**
	Total for question 14	**6**

Question Number	Answer		Mark
15(a)	Use of $z = \frac{\Delta\lambda}{\lambda}$	(1)	
	$\lambda_o = 1.60 \times 10^{-6}$ m	(1)	2
	Example of calculation		
	$z = \frac{\Delta\lambda}{\lambda} = \frac{(\lambda_o - 134 \times 10^{-9}\ \text{m})}{134 \times 10^{-9}\ \text{m}} = 10.96$		
	$\therefore \lambda_o = (10.96 \times 134 \times 10^{-9}\ \text{m}) + 134 \times 10^{-9}\ \text{m} = 1.60 \times 10^{-6}\ \text{m}$		
15(b)	*d* between 13 and 14 ($\times 10^9$ ly)	(1)	
	Use of $s = ut$	(1)	
	$s = 1.3 \times 10^{26}$ (m) [Accept answers in range $1.2 \times 10^{26} \rightarrow 1.3 \times 10^{26}$]	(1)	3
	Example of calculation		
	$d = 13.4 \times 10^9$ ly		
	1 ly = 3.0×10^8 m s^{-1} $\times 3.15 \times 10^7$ s $= 9.45 \times 10^{15}$ m		
	$s = 9.45 \times 10^{15}$ m $\times 13.4 \times 10^9 = 1.26 \times 10^{26}$ m		
15(c)	Very distant galaxies have (very) large red shifts	(1)	
	So their light has become infrared when it arrives (at the telescope) [MP2: Do not credit statements that light is emitted in IR region of spectrum]	(1)	2
	Total for question 15		**7**

Question Number	Answer	Mark
16(a)	f_{max} read from graph **(1)** Use of $c = f\lambda$ **(1)** Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K **(1)** T = 3100 (K) **(1)** <u>Example of calculation</u> $f_{max} = 3.2 \times 10^{14}$ Hz $\lambda_{max} = \frac{3.0 \times 10^8 \text{ m s}^{-1}}{3.2 \times 10^{14} \text{ Hz}} = 9.38 \times 10^{-7}$ m $T = \frac{2.898 \times 10^{-3} \text{ m K}}{9.38 \times 10^{-7} \text{ m}} = 3090$ K	4
16(b)	Use of $A = 4\pi r^2$ **(1)** Use of $L = \sigma A T^4$ **(1)** $L = 4.52 \times 10^{24}$ W [ecf from (a)] **Or** T = 5300 K [ecf from (a)] **(1)** Conclusion made from comparison of calculated L with 10% of luminosity of the Sun [3.83×10^{25} W] **Or** conclusion made from comparison of T for a star with 10% of luminosity of the Sun with T calculated in (a) **(1)** <u>Example of calculation</u> $L = 4\pi\ (2.62 \times 10^8 \text{ m})^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}\ (3100 \text{ K})^4$ $L = 4.52 \times 10^{24}\ W$ $\frac{L}{L_{Sun}} \times 100\% = \frac{4.52 \times 10^{24}\ W}{3.83 \times 10^{26}\ W} \times 100\% = 1.18\%$ Luminosity of Gliese-876 is less than 10% of Sun's luminosity. so claim is correct. Temperature of Gliese-876 is less than surface temperature of a star with 10% of the Sun's luminosity, so claim is correct.	4
	Total for question 16	**8**

Question Number	Answer		Mark
17(a)(i)	Use of $F = \frac{GMm}{r^2}$	(1)	
	$F = 7.3 \times 10^{17}$ (N)	(1)	2
	Example of calculation $F = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 1.99 \times 10^{30}\ \text{kg} \times 9.38 \times 10^{20}\ \text{kg}}{(4.14 \times 10^{11}\ \text{m})^2}$ $\therefore F = 7.26 \times 10^{17}$ N		
17(a)(ii)	Use of $F = m\omega^2 r$	(1)	
	Use of $\omega = \frac{2\pi}{T}$	(1)	
	Conversion to years	(1)	
	T = 4.6 year [ecf from (i)]	(1)	
	Or		
	Use of $F = \frac{mv^2}{r}$	(1)	
	Use of $v = \frac{2\pi r}{T}$	(1)	
	Conversion to years	(1)	
	T = 4.6 year [ecf from (i)]	(1)	4
	Example of calculation $\omega = \sqrt{\frac{F}{mr}} = \sqrt{\frac{7.26 \times 10^{17}\ \text{N}}{9.38 \times 10^{20}\ \text{kg} \times 4.14 \times 10^{11}\ \text{m}}} = 4.32 \times 10^{-8}\ \text{rad s}^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi\ \text{rad}}{4.32 \times 10^{-8}\ \text{rad s}^{-1}} = 1.45 \times 10^{8}\ \text{s}$ $\therefore T = \frac{1.45 \times 10^{8}\ \text{s}}{3.15 \times 10^{7}\ \text{s year}^{-1}} = 4.61\ \text{year}$		

17(b)	Use of $g = \frac{GM}{r^2}$ to calculate g for Ceres Ratio of field strengths calculated **Or** 5% of g for Mercury calculated g_c is 7.7% of g_m so claim is inaccurate **Or** $g_c = 0.283\ \text{N kg}^{-1}$ and 5% of $g_m = 0.185\ \text{N kg}^{-1}$, so claim is inaccurate <u>Example of calculation</u> $g_c = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 9.38 \times 10^{20}\ \text{kg}}{(4.7 \times 10^5\ \text{m})^2} = 0.283\ \text{N kg}^{-1}$ $\therefore \frac{g_c}{g_m} = \frac{0.283\ \text{N kg}^{-1}}{3.7\ \text{N kg}^{-1}} = 0.0765$	**(1)** **(1)** **(1)**	**3**
	Total for question 17		**9**

Question Number	Answer	Mark
18(a)(i)	X is a neutron **(1)**	**1**
18(a)(ii)	Decrease in mass calculated **(1)** Energy in (G)eV calculated from mass difference **(1)** Conversion of energy in eV to J **(1)** Energy released = 8.0×10^{-14} (J) **(1)** <u>Example of calculation</u> $\Delta m = (25.1333 + 3.7274)\ \text{GeV/c}^2 - (27.9206 + 0.9396)\ \text{GeV/c}^2$ $= 5.00 \times 10^{-4}\ \text{GeV/c}^2$ $\Delta E = 5.00 \times 10^{-4}$ GeV $\Delta E = 5.00 \times 10^{-4} \times 10^{9}\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J eV}^{-1} = 8.0 \times 10^{-14}\ \text{J}$	**4**
18(b)	Positrons annihilate with electrons to produce gamma radiation **(1)** Gamma radiation can penetrate the body **(1)** Half life is long enough to allow the procedure to be performed **(1)** Half life is short enough to avoid unnecessarily large radiation dose **(1)**	**4**
	Total for question 18	**9**

Question Number	Answer		Mark
19(a)	(When the object is displaced): there is a (resultant) force that is proportional to the displacement from the equilibrium position and (always) acting towards the equilibrium position [Accept force is in the opposite direction to displacement] (Accept 'acceleration' for 'force') (For equilibrium position accept: undisplaced point/position or fixed point/position or central point/position, do not accept mean position)	 **(1)** **(1)**	**2**
19(b)(i)	Frequency/period calculated from oscillations per minute *T* = 0.22 s [can be seen on graph] Use of $\omega = 2\pi f$ **Or** Use of $\omega = \frac{2\pi}{T}$ Use of $v = A\omega \sin \omega t$ *v* = 1.1 m s^{-1} [can be seen on graph] At least 1 cycle of a sinusoidal graph with calculated values of *v* and *T* on axes <u>Example of calculation</u> $f = \frac{270\ \text{min}^{-1}}{60\ \text{s min}^{-1}} = 4.5\ \text{Hz}$ $\omega = 2\pi\ \text{rad} \times 4.5\ \text{s}^{-1} = 28.3\ \text{rad s}^{-1}$ $v = \left(\frac{8.0 \times 10^{-2}\ \text{m}}{2}\right) \times 28.3\ \text{s}^{-1} = 1.13\ \text{m s}^{-1}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
19(b)(ii)	Use of $a = -\omega^2 x$ *a* = 32 m s^{-2} [ecf from (i)] <u>Example of calculation</u> $a = -(28.3\ \text{s}^{-1})^2 \times 4.0 \times 10^{-2}\ \text{m} = 32.0\ \text{m s}^{-2}$	**(1)** **(1)**	**2**

19(b)(iii)	The particles are free to move inside the can **Or** Not all the particles will move with simple harmonic motion **Or** Amplitude/frequency/period of oscillation of particles is different to amplitude of can **Or** The particles may continue to move upwards as the can starts moving downwards **Or** The particles may collide with each other **Or** the force on the paint particles is not equal to the force on the can. **(1)**	**1**
	Total for question 16	**11**

Question Number	Answer	Mark
20(a)	A massive nucleus splits into two (or more) smaller nuclei/fragments (of roughly equal mass and some neutrons) **(1)**	**1**
20(b)(i)	Top line correct **(1)** Bottom line correct **(1)** $^{137}_{55}\mathrm{Cs} \rightarrow {}^{137}_{56}\mathrm{Ba} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}$	**2**
20(b)(ii)	Momentum is conserved (so the Ba nucleus recoils) **(1)** Energy released is shared (randomly) between the β^{-} and $\bar{\nu}$ **Or** the energy is shared between the 3 particles in the decay **(1)**	**2**

20(c)(i)	Use of $N = \frac{\text{mass of caesium}}{\text{mass of caesium atom}}$ Use of 1 u = 1.66×10^{-27} kg Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ Use of $A = \lambda N$ $A = 7.7 \times 10^{16}$ Bq Valid conclusion based on calculated value of activity Example of calculation $N = \frac{24 \text{ kg}}{(136.9 \times 1.66 \times 10^{-27}) \text{ kg}} = 1.06 \times 10^{26}$ $\lambda = \frac{\ln 2}{(30.2 \times 3.15 \times 10^{7})\text{s}} = 7.29 \times 10^{-10} \text{ s}^{-1}$ $A = -7.29 \times 10^{-10} \text{ s}^{-1} \times 1.06 \times 10^{26} = -7.73 \times 10^{16}$ Bq 7.7×10^{16} Bq is not equal to 7.3×10^{16} Bq (so statement is incorrect) **Or** 7.7×10^{16} Bq is approximately equal to 7.3×10^{16} Bq (so statement is correct)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
20(c)(ii)	Use of 500 Bq per 100 g to calculate initial count rate Use of $A = A_0 e^{-\lambda t}$ $t = 5.37 \times 10^{9}$ s [171 year] [ecf from (i)] Example of calculation $A_0 = \frac{1}{4} \times 500 \text{ Bq} = 125 \text{ Bq}$ $A = \frac{150}{60 \text{ s}} = 2.5 \text{ Bq}$ $2.5 \text{ Bq} = 125 \text{ Bq} e^{-7.28 \times 10^{-10} \text{ s}^{-1} \times t}$ $\therefore \ln \frac{2.5 \, Bq}{125 \, Bq} = -7.28 \times 10^{-10} \, s^{-1} \times t$ $\therefore t = \frac{-3.91}{-7.28 \times 10^{-10} \text{ s}^{-1}} = 5.37 \times 10^{9}$ s	**(1)** **(1)** **(1)**	**3**
	Total for question 20		**14**

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