Pearson Edexcel

Mark Scheme (Results)

Summer 2024

Pearson Edexcel International Advanced Level In Physics (WPH15)
Paper 01 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 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 in 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.

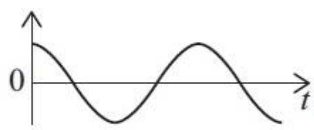
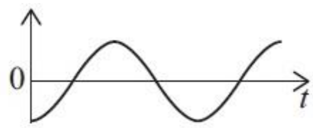
4.3 The mark scheme will show a correctly worked answer for illustration only.

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.

Question Number	Answer	Mark
1	**D is the only correct answer (density and surface temperature both increase)** A is not the correct answer, as surface temperature and density increases B is not the correct answer, as density increases C is not the correct answer, as surface temperature increases	1
2	**D is the only correct answer (trigonometric parallax)** A is not the correct answer, as Doppler shift lets relative motion be determined B is not the correct answer, as an HR-diagram shows luminosity v temperature C is not the correct answer, as Hubble's law applies to galaxies	1
3	**A is the only correct answer (4*E*)** B is not the correct answer, as $E_k = \frac{1}{2}mv^2$ and $v_{max} = \omega A$ C is not the correct answer, as $E_k = \frac{1}{2}mv^2$ and $v_{max} = \omega A$ D is not the correct answer, as $E_k = \frac{1}{2}mv^2$ and $v_{max} = \omega A$	1
4	**C is the only correct answer (mass will oscillate at the frequency of the vibration generator.)** A is not the correct answer, as the amplitude is only a maximum for resonance B is not the correct answer, as the mass is forced to oscillate at the vibrator frequency D is not the correct answer, as the energy transfer is only a maximum for resonance	1
5	**D is the only correct answer (we cannot predict when a decay will take place)** A is not the correct answer, as "natural" is not the same as "random" B is not the correct answer, as "spontaneous" is not the same as "random" C is not the correct answer, as this defines "spontaneous"	1
6	**A is the only correct answer (gravitational force and velocity both decrease)** B is not the correct answer, as velocity decreases C is not the correct answer, as gravitational force decreases D is not the correct answer, as gravitational force and velocity decrease	1
7	**B is the only correct answer (red dwarf star)** A is not the correct answer, as these have high luminosity and high temperature C is not the correct answer, as these have a high luminosity D is not the correct answer, as these have a high temperature	1
8	**A is the only correct answer ($\frac{1}{\sqrt{2}}$)** B is not the correct answer, as $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ C is not the correct answer, as $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ D is not the correct answer, as $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	1
9	**C is the only correct answer** 	1
10	**B is the only correct answer** 	1

Question Number	Answer		Mark
11	**EITHER** ($V_{\text{grav}} = \frac{-GM}{r}$, so) gravitational potential $\propto \frac{1}{r}$ **Or** $V_{\text{grav}} = \frac{-GM}{r}$ and G and M are constant [Allow a graph or a description in words to describe an inverse relationship as long as potential equation is given]	**(1)**	
	The equipotential surfaces become further apart with increasing distance (from Earth)	**(1)**	
	OR Equal work needed to transfer a body from X to Y and from Y to Z	**(1)**	
	(Mean) gravitational force is larger between X and Y, so distance moved must be smaller	**(1)**	**2**
	Total for question 11		**2**

Question Number	Answer		Mark
12	Use of $g = \frac{GM}{r^2}$	**(1)**	
	Use of $W = mg$	**(1)**	
	$W = 77$ N	**(1)**	**3**
	<u>Example of calculation</u> $g = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 3.40 \times 10^{21}\ \text{kg}}{(7.88 \times 10^{5}\ \text{m})^2} = 0.365\ \text{N kg}^{-1}$ $F = 210\ \text{kg} \times 0.365\ \text{N kg}^{-1} = 76.7\ \text{N}$		
	Total for question 12		**3**

Question Number	Answer	Mark
13(a)	<u>Upthrust</u> on airship is equal to the <u>weight</u> of the airship **(1)** (so) resultant force on the airship is zero (so airship floats in the air) **Or** (vertically) balanced forces act on the airship **(1)** If neither MP seen, max 1 mark for statement indicating that upwards force is equal to downwards force.	**2**
13(b)	Use of $pV = NkT$ **(1)** Conversion of temperature to K **(1)** Use of $M = Nm$ **(1)** M = 1200 kg **(1)** <u>Example of calculation</u> $N = \frac{pV}{kT} = \frac{1.08 \times 10^5 \text{ Pa} \times 7020 \text{ m}^3}{1.38 \times 10^{-23} \text{ m}^2 \text{ kg s}^{-2} \text{ K}^{-1} \times (273 + 25) \text{ K}} = 1.84 \times 10^{29}$ $M = 1.84 \times 10^{29} \times 6.64 \times 10^{-27} \text{ kg} = 1220 \text{ kg}$	**4**
	Total for question 13	**6**

Question Number	Answer	Mark
14(a)	The alpha radiation will not penetrate the lead **Or** The lead will absorb the alpha radiation **(1)**	**1**
14(b)	**EITHER** Determine the background count (rate) **(1)** Subtract background count (rate) from the recorded count (rate) to eliminate systematic error **Or** Subtract background count from the recorded count to prevent the count rate being overestimated **(1)** **OR** Record the count for a longer time interval **Or** Record the count more than once and calculate a mean value **(1)** This will reduce the effect of random variation on the count rate **Or** this will decrease the percentage uncertainty **(1)**	**2**
14(c)	**EITHER** One pair of values read from curve **(1)** Use of $R = 60e^{-\mu x}$ with values read from graph **(1)** $\mu = 0.30\ \text{cm}^{-1} \rightarrow 0.36\ \text{cm}^{-1}$ **(1)** **OR** Tangent drawn at $x = 0$ **(1)** 1/(x-intercept of tangent) determined **Or** gradient of tangent divided by y-intercept (R_0) **(1)** [MP2 dependent on MP1] $\mu = 0.30\ \text{cm}^{-1} \rightarrow 0.39\ \text{cm}^{-1}$ **(1)** [Accept μ in m^{-1}] Example of calculation $\ln R = \ln 60 - \mu x$ $\therefore \mu = \frac{\ln 60 - \ln R}{x} = \frac{4.094 - \ln 43}{1.0} = 0.333\ \text{cm}^{-1}$	**3**
	Total for question 14	**6**

Question Number	Answer	Mark
15(a)	Use of $\Delta E = mL$ **(1)** Use of $\Delta E = mc\Delta\theta$ **(1)** $\Delta E = 1.32 \times 10^{11}$ (J) **(1)** <u>Example of calculation</u> $\Delta E = 3.53 \times 10^5 \text{kg} \times 3.36 \times 10^5 \text{ J kg}^{-1} = 1.19 \times 10^{11} \text{ J}$ $\Delta E = 3.53 \times 10^5 \text{ kg} \times 2.09 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1} \times (0-(-18)) \text{ K}$ $= 1.33 \times 10^{10} \text{ J}$ $\Delta E = 1.19 \times 10^{11} \text{ J} + 1.33 \times 10^{10} \text{ J} = 1.319 \times 10^{11} \text{ J}$	3
15(b)	Surface area of top of ice floe calculated [453 m^2] **(1)** Intensity at sea level calculated using 56% [767 W m^{-2}] **(1)** Use of $I = \frac{P}{A}$ **(1)** Use of $P = \frac{\Delta W}{\Delta t}$ **(1)** t = 4.4 days [4.3 days if "show that" value used] (ecf from (a)) **(1)** **Or** $E = 2.10 \times 10^{11}$ J for 7 days 4.4 days is less than 7 days so claim is not correct **Or** $1.32 \times 10^{11} \text{ J} < 2.10 \times 10^{11}$ J so claim is not correct **Or** Correct conclusion based on comparison of candidate's calculated values **(1)** <u>Example of calculation</u> $P = 0.56 \times 1370 \text{ W m}^{-2} \times 453 \text{ m}^2 = 3.48 \times 10^5 \text{ W}$ $t = \frac{1.32 \times 10^{11} \text{ J}}{3.48 \times 10^5 \text{ J s}^{-1}} = 3.79 \times 10^5 \text{ s}$ $t = \frac{3.79 \times 10^5 \text{ s}}{8.64 \times 10^4 \text{ s day}^{-1}} = 4.39 \text{ days}$	6
	Total for question 15	**9**

Question Number	Answer		Mark
16(a)	Use of $I = \frac{L}{4\pi d^2}$	(1)	
	Use of $L = \sigma A T^4$	(1)	
	Use of $A = 4\pi r^2$	(1)	
	Use of $\lambda_{max} T = 2.898 \times 10^{-3}$ m K	(1)	
	$\lambda_{max} = 5.64 \times 10^{-7}$ m	(1)	5
	<u>Example of calculation</u> $1.05 \times 10^{-9}\ \text{W m}^{-2} = \frac{L}{4\pi \times (9.94 \times 10^{16}\ \text{m})^2}$ $L = 4\pi \times (9.94 \times 10^{16}\ \text{m})^2 \times 1.05 \times 10^{-9}\ \text{W m}^{-2} = 1.30 \times 10^{26}$ W $A = 4\pi \times (5.12 \times 10^8\ \text{m})^2 = 3.29 \times 10^{18}\ \text{m}^2$ $1.30 \times 10^{26}\ \text{W} = 5.67 \times 10^{-8} \text{W m}^{-2}\text{K}^{-4} \times 3.29 \times 10^{18}\ \text{m}^2 \times T^4$ $T = \sqrt[4]{\frac{1.30 \times 10^{26}\ \text{W}}{5.67 \times 10^{-8}\ \text{W m}^{-2}\text{K}^{-4} \times 3.29 \times 10^{18}\ \text{m}^2}} = 5140$ K $\lambda_{max} = \frac{2.898 \times 10^{-3}\ \text{m K}}{5140\ \text{K}} = 5.64 \times 10^{-7}$m		
16(b)	Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ [Allow a 2 step approach using a calculation of the red shift, z]	(1)	
	$\Delta\lambda = 0.025$ nm	(1)	
	0.025 (nm) < 0.05 (nm), so no wavelength change could be detected **Or** comparison of calculated value with 0.05 (nm) and consistent conclusion made.	(1)	3
	<u>Example of calculation</u> $\frac{\Delta\lambda}{480\ \text{nm}} = \frac{1.55 \times 10^4\ \text{m s}^{-1}}{3.00 \times 10^8\ \text{m s}^{-1}}$ $\Delta\lambda = 480\ \text{nm} \times 5.17 \times 10^{-5} = 0.0248$ nm		
	Total for question 16		**8**

Question Number	Answer	Mark
17(a)	Top line correct **(1)** Bottom line correct **(1)** $^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\overline{\nu}_{e}$	**2**
17(b)(i)	Calculation of total activity **(1)** Conversion of half life to seconds **(1)** Use of $\lambda t_{1/2} = \ln 2$ **(1)** Use of $A = \lambda N$ **(1)** Use of $M = N \times m$ **(1)** $M = 7.3 \times 10^{-10}$ kg **Or** $M = 4.1 \times 10^{17}$ GeV/c^2 **(1)** Example of calculation $A = 51.8 \times 10^{6}\ \text{s}^{-1} \times 65\ \text{kg} = 3.37 \times 10^{9}\ \text{Bq}$ $\lambda = \frac{\ln 2}{8.02 \times 24 \times 3600\ \text{s}} = 1.00 \times 10^{-6}\ \text{s}^{-1}$ $N = \frac{3.37 \times 10^{9}\ \text{Bq}}{1.00 \times 10^{-6}\ \text{s}^{-1}} = 3.37 \times 10^{15}$ $m = \frac{122 \times 10^{9}\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J eV}^{-1}}{(3.00 \times 10^{8}\ \text{m s}^{-1})^{2}} = 2.17 \times 10^{-25}\ \text{kg}$ $\therefore M = 3.37 \times 10^{15} \times 2.17 \times 10^{-25}\ \text{kg} = 7.31 \times 10^{-10}\ \text{kg}$	**6**
17(b)(ii)	Use of $A = A_0 e^{-\lambda t}$ with A = 2.35 GBq **(1)** $A_0 = 2.6$ GBq (ecf from (b)(i) for value of λ) **(1)** Example of calculation $2.35\ \text{GBq} = A_0 e^{-1.00 \times 10^{-6}\ \text{s}^{-1} \times 24 \times 3600\ \text{s}}$ $A_0 = \frac{2.35\ \text{GBq}}{e^{-1.00 \times 10^{-6}\ \text{s}^{-1} \times 24 \times 3600\ \text{s}}} = 2.56\ \text{GBq}$	**2**
	Total for question 17	**10**

Question Number	Answer	Mark
18(a)	Gravitational force equated to centripetal force **(1)** Substitution of $\omega = \frac{2\pi}{T}$ **Or** Substitution of $v = \frac{2\pi r}{T}$ **(1)** Algebra to obtain required expression **(1)** <u>Example of derivation</u> $m\omega^2 r = \frac{GMm}{r^2}$ $m\left(\frac{2\pi}{T}\right)^2 r = \frac{GMm}{r^2}$ $T^2 = \frac{4\pi^2}{GM} r^3$	3
18(b)(i)	Use of $T^2 = \frac{4\pi^2 r^3}{GM}$ **(1)** $T = 8.3 \times 10^{15}$ (s) **(1)** <u>Example of calculation</u> $T = \sqrt{\frac{4\pi^2 \times (5.7 \times 10^{20}\ \text{m})^3}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 8.0 \times 10^{11} \times 1.99 \times 10^{30}\ \text{kg}}}$ $\therefore T = 8.30 \times 10^{15}$ s	2
18(b)(ii)	The actual period is (much) smaller than the calculated value **(1)** So the mass of the galaxy must be greater than 8.0×10^{11} solar masses [accept the given mass for the numerical value] **Or** the gravitational force on the star must be bigger (than assumed) **(1)** There must be matter that does not emit em-radiation **Or** There must be matter that we cannot detect via em-radiation [Accept "there must be matter that we cannot see"] **(1)** (This suggests that) there is dark matter **(1)**	4
	Total for question 18	**9**

Question Number	Answer		Mark
19(a)(i)	Mass defect calculated	**(1)**	
	Conversion between u and kg	**(1)**	
	Use of $\Delta E = c^2 \Delta m$	**(1)**	
	$\Delta E = 4.27 \times 10^{-12}$ (J)	**(1)**	**4**
	Example of calculation Mass defect = (4 × 1.0078 u) − 4.0026 u = 0.0286 u Mass defect = 0.0286 u × 1.66×10^{-27} kg u^{-1} = 4.75×10^{-29} kg $\Delta E = (3.00 \times 10^8 \text{ m s}^{-1})^2 \times 4.75 \times 10^{-29} \text{ kg} = 4.27 \times 10^{-12}$ J		
19(a)(ii)	Use of 10% with mass, energy or power [or in final comparison]	**(1)**	
	Energy released per fusion used (ecf from (a)(i))	**(1)**	
	Use of 1 u = 1.66×10^{-27} kg to obtain mass of 4 protons	**(1)**	
	Use of 1 year = 3.15×10^7 s	**(1)**	
	$t = 7 \times 10^9$ year, which is less than 9×10^9 year so claim inaccurate **Or** $P = 3.13 \times 10^{26}$ W, which is less than 3.83×10^{26} W so claim inaccurate **Or** $E = 8.87 \times 10^{43}$ J, which is less than 1.09×10^{44} J so claim inaccurate **Or** 12% of hydrogen used, which is greater than 10%, so claim is inaccurate [Must see unit for calculated value somewhere in the solution]	**(1)**	**5**
	Example of calculation $L = (\text{energy released per helium nucleus formed}) \times (\text{rate of fusion})$ $(\text{rate of fusion}) = \frac{3.83 \times 10^{26}\text{ W}}{4.27 \times 10^{-12}\text{ J}} = 8.97 \times 10^{37}\text{ s}^{-1}$ $\text{mass per second} = 8.97 \times 10^{37}\text{ s}^{-1} \times 4 \times 1.0078 \times 1.66 \times 10^{-27}\text{ kg}$ $= 6.00 \times 10^{11}\text{ kg s}^{-1}$ $\text{time} = \frac{0.1 \times 1.39 \times 10^{30}\text{ kg}}{6.00 \times 10^{11}\text{ kg s}^{-1}} = 2.32 \times 10^{17}\text{ s}$ $\text{time} = \frac{2.32 \times 10^{17}\text{s}}{3.15 \times 10^{7}\text{s year}^{-1}} = 7.35 \times 10^{9}\text{ year}$ [“show that” value gives 7.35×10^9 year]		

Question number	Answer	Mark
*19(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 indicative content.	

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

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

Indicative content

IC1 Hydrogen fusion occurs in the core of the (main sequence) star

IC2 Hydrogen (in the core) runs out

IC3 The rate of fusion decreases and the star contracts

IC4 The temperature rises (in the core) and fusion of helium begins

IC5 The star expands (and cools) to form a red giant star

IC6 (Helium) fusion stops and the star collapses to a white dwarf star **Or** helium runs out and the star collapses to a white dwarf star

6

	Total for question 19	**15**

Question Number	Answer		Mark
20(a)	There is a (resultant) acceleration / force that is proportional to the displacement from the equilibrium position and (always) acting towards the equilibrium position (An equation with symbols defined correctly is a valid response for both marks For equilibrium position accept: undisplaced point / position or fixed point / position or central point / position)	**(1)** **(1)**	**2**
20(b)(i)	Match the natural frequency (of the dampers) to the driving frequency So that there is an efficient / maximum transfer of energy (to the dampers)	**(1)** **(1)**	**2**
20(b)(ii)	Use of $\rho = \frac{m}{V}$ Use of $T = 1 / f$ Use of $T = 2\pi\sqrt{\frac{m}{k}}$ $k = 3.1 \times 10^5$ N m^{-1} <u>Example of calculation</u> $m = (5.20 \text{ m})^2 \times 0.90 \text{ m} \times 11300 \text{ kg m}^{-3} = 2.75 \times 10^5 \text{ kg}$ $T = \frac{1}{f} = \frac{1}{0.17 \text{ Hz}} = 5.88 \text{ s}$ $k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2 \times 2.75 \times 10^5 \text{ kg}}{(5.88 \text{ s})^2} = 3.14 \times 10^5 \text{ N m}^{-1}$	**(1)** **(1)** **(1)** **(1)**	**4**
20(b)(iii)	**MAX 2** The motion of the box is (strongly) damped Amplitude <u>at resonance</u> is small Lead box has a large mass/inertia A large force is needed to set box into motion	 **(1)** **(1)** **(1)** **(1)**	**2**
20(c)	Work is done (by roller) as oil is forced through the holes So energy is transferred from the building (and not returned) **Or** energy is transferred to the surroundings (and not returned) [Accept “dissipated” for “transferred to surroundings”]	**(1)** **(1)**	**2**
	Total for question 20		**12**