Mark Scheme (Results)

October 2022

Pearson Edexcel International Advanced Level
In Physics (WPH15/01)
Paper 5: Thermodynamics, Radiation, Oscillations and Cosmology

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, $m = 1.00 \times 10^3 \text{ kg m}^{-3} \times 1.8 \times 10^{-5} \text{ m}^3 = 0.018 \text{ kg}$ $m = 0.018 \text{ kg s}^{-1} \times 9 \times 60 \text{ s} = 9.72 \text{ kg}$ $\Delta E = 9.72 \text{ kg} \times 4180 \text{ J kg}^{-1} \text{ K}^{-1} \times (38 - 15) \text{ K} = 9.34 \times 10^5 \text{ J}$ 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)** <u>Example of calculation</u> $13T = (6.9 - 0.2) \times 24$ hours = 160.8 hours $T = \dfrac{160.8 \text{ hours}}{13} = 12.4 \text{ hours}$	**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**
	<u>Example of calculation</u>		
	$z = \frac{\Delta\lambda}{\lambda} = \frac{(\lambda_o - 134 \times 10^{-9}\ \text{m})}{134 \times 10^{-9}\ \text{m}} = 10.96$		
	$\therefore \lambda_o = (10.96 \times 134 \times 10^{-9}\ \text{m}) + 134 \times 10^{-9}\ \text{m} = 1.60 \times 10^{-6}\ \text{m}$		
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**
	<u>Example of calculation</u>		
	$d = 13.4 \times 10^9$ ly		
	1 ly = 3.0×10^8 m s^{-1} $\times 3.15 \times 10^7$ s = 9.45×10^{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)**	**4**
	<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		
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)**	**4**
	<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.		
	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
	<u>Example of calculation</u>		
	$F = \frac{6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}} \times 1.99 \times 10^{30}\ \mathrm{kg} \times 9.38 \times 10^{20}\ \mathrm{kg}}{(4.14 \times 10^{11}\ \mathrm{m})^2}$		
	$\therefore F = 7.26 \times 10^{17}\ \mathrm{N}$		
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
	<u>Example of calculation</u>		
	$\omega = \sqrt{\frac{F}{mr}} = \sqrt{\frac{7.26 \times 10^{17}\ \mathrm{N}}{9.38 \times 10^{20}\ \mathrm{kg} \times 4.14 \times 10^{11}\ \mathrm{m}}} = 4.32 \times 10^{-8}\ \mathrm{rad\ s^{-1}}$		
	$T = \frac{2\pi}{\omega} = \frac{2\pi\ \mathrm{rad}}{4.32 \times 10^{-8}\ \mathrm{rad\ s^{-1}}} = 1.45 \times 10^{8}\ \mathrm{s}$		
	$\therefore T = \frac{1.45 \times 10^{8}\ \mathrm{s}}{3.15 \times 10^{7}\ \mathrm{s\ year^{-1}}} = 4.61\ \mathrm{year}$		

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 **(1)** and (always) acting towards the equilibrium position **(1)** [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)	**2**
19(b)(i)	Frequency/period calculated from oscillations per minute **(1)** T = 0.22 s [can be seen on graph] **(1)** Use of $\omega = 2\pi f$ **Or** Use of $\omega = \frac{2\pi}{T}$ **(1)** Use of $v = A\omega \sin \omega t$ **(1)** $v = 1.1\ \text{m s}^{-1}$ [can be seen on graph] **(1)** At least 1 cycle of a sinusoidal graph with calculated values of v and T on axes **(1)** <u>Example of calculation</u> $f = \frac{270\ \text{min}^{-1}}{60\ \text{s min}^{-1}} = 4.5\ \text{Hz}$ $\omega = 2\pi\ \text{rad} \times 4.5\ \text{s}^{-1} = 28.3\ \text{rad s}^{-1}$ $v = \left(\frac{8.0 \times 10^{-2}\ \text{m}}{2}\right) \times 28.3\ \text{s}^{-1} = 1.13\ \text{m s}^{-1}$	**6**
19(b)(ii)	Use of $a = -\omega^2 x$ **(1)** $a = 32\ \text{m s}^{-2}$ [ecf from (i)] **(1)** <u>Example of calculation</u> $a = -(28.3\ \text{s}^{-1})^2 \times 4.0 \times 10^{-2}\ \text{m} = 32.0\ \text{m s}^{-2}$	**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)** $^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}$	**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 <u>Example of calculation</u> $N = \frac{24 \text{ kg}}{(136.9 \times 1.66 \times 10^{-27}) \text{ kg}} = 1.06 \times 10^{26}$ $\lambda = \frac{\ln 2}{(30.2 \times 3.15 \times 10^{7})\text{s}} = 7.29 \times 10^{-10} \text{ s}^{-1}$ $A = -7.29 \times 10^{-10} \text{ s}^{-1} \times 1.06 \times 10^{26} = -7.73 \times 10^{16}$ 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)] <u>Example of calculation</u> $A_0 = \frac{1}{4} \times 500 \text{ Bq} = 125 \text{ Bq}$ $A = \frac{150}{60 \text{ s}} = 2.5 \text{ Bq}$ $2.5 \text{ Bq} = 125 \text{ Bq} e^{-7.28 \times 10^{-10} \text{ s}^{-1} \times t}$ $\therefore \ln \frac{2.5\ Bq}{125\ Bq} = -7.28 \times 10^{-10}\ s^{-1} \times t$ $\therefore t = \frac{-3.91}{-7.28 \times 10^{-10} \text{ s}^{-1}} = 5.37 \times 10^{9}$ s	**(1)** **(1)** **(1)**	**3**
	Total for question 20		**14**