Mark scheme (Unused)

January 2022

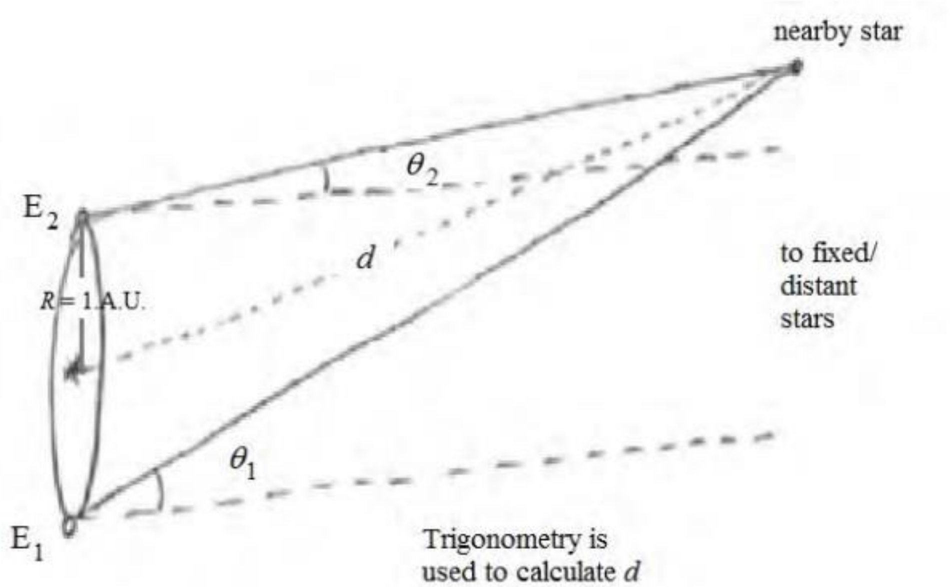
Pearson Edexcel International Advanced Level
In Physics (WPH15/01)
Paper 5: Thermodynamics, Radiation, Oscillations and Cosmology

Question Number	Answer	Mark
1	**B is the correct answer** A is not correct, as binding energy is not related to temperature C is not correct, as a high collision rate is determined by the density D is not correct, as a very high temperature doesn't mean a high density	**(1)**
2	**C is the correct answer,** as $g = \frac{GM}{r^2}$ and $M = \rho V$	**(1)**
3	**B is the correct answer** A is not correct, as the electronic charge has been used to convert the mass C is not correct, as the conversion of mass to kg is incorrect D is not correct, as the conversion of mass to kg is incorrect	**(1)**
4	**D is the correct answer,** A is incorrect, as the amplitude decreases over time for a damped oscillation B is incorrect, as the amplitude stays constant over time for a free oscillation C is incorrect, as the amplitude may stay constant or decrease over time for a natural oscillation	**(1)**
5	**D is the correct answer,** as the count rate halves for each thickness of 1.5 cm	**(1)**
6	**C is the correct answer,** as $v_{\mathrm{max}} = 2\pi f A$	**(1)**
7	**A is the correct answer,** as $I = \frac{L}{4\pi d^2}$ gives d, so I and L must be known	**(1)**
8	**B is the correct answer,** as it is incorrect to say frequency decreases over time	**(1)**
9	**B is the correct answer** A is incorrect, as X is a diagram for a very old star cluster (white dwarf stars present) C and D are incorrect, as Z is a diagram for a medium age star cluster (red giant, but no white dwarf stars present)	**(1)**
10	**C is the correct answer** A is incorrect, as there are for more nucleons in a nucleus of ^{238}U than in ^{120}Sn B is incorrect, as a nucleus of ^{120}Sn has a higher B.E./nucleon than ^{16}O D is incorrect, as we cannot deduce this statement from the graph.	**(1)**

Question Number	Answer	Mark
11	Use of $V = \frac{4}{3}\pi r^3$ (1) Use of $pV = NkT$ (1) Conversion of temperature to kelvin (1) $N = 6.76 \times 10^{23}$ (1) <u>Example of calculation</u> $V = \frac{4}{3}\pi\,(0.185\ \text{m})^3 = 2.65\times10^{-2}\ \text{m}^3$ $N = \frac{pV}{kT} = \frac{1.04\times10^{5}\,\text{Pa}\times2.65\times10^{-2}\ \text{m}^3}{1.38\times10^{-23}\ \text{J K}^{-1}\times(273+22.5)\ \text{K}} = 6.76\times10^{23}$	**4**
	Total for question 11	**4**

Question Number	Answer	Mark
12	Use of $\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ (1) Use of $v = H_0 d$ (1) $d = 1.4 \times 10^{24}$ m (1) <u>Example of calculation</u> $v = \frac{\Delta\lambda}{\lambda}c = \frac{(438.6-434.1)\times10^{-9}\text{m}}{434.1\times10^{-9}\text{ m}} \times 3.00\times10^{8}\text{ m s}^{-1} = 3.11\times10^{6}\text{ m s}^{-1}$ $d = \frac{3.11\times10^{6}\text{ m s}^{-1}}{2.3\times10^{-18}\text{ s}^{-1}} = 1.35\times10^{24}\text{ m}$	**3**
	Total for question 12	**3**

Question Number	Answer		Mark
13	**MAX 4** The student is correct to say that the rate of decay decreases over time However, the uranium doesn't become more stable, the number of unstable uranium nuclei decreases. The student should have said that radiation is emitted from the nucleus [accept atom] The student was wrong to say that the particles emitted are radioactive Because the emitted particles do not decay In a time equal to the half-life the number of unstable nuclei (and not the mass) decreases by 50%. Because the product nuclei are nearly as massive as the unstable nuclei	(1) (1) (1) (1) (1) (1) (1)	**4**
	Total for question 13		**4**

Question Number	Answer		Mark
14(a)	The star is viewed from two positions at 6 month intervals **Or** the star is viewed from opposite ends of the diameter of the Earth's orbit about the Sun The change in angular position of the star against backdrop of distant/fixed stars is measured Trigonometry is used to calculate the distance to the star [Do not accept Pythagoras] The diameter/radius of the Earth's orbit about the Sun must be known Full marks may be obtained from a suitably annotated diagram  [Accept the symmetrical diagram seen in many text books]	(1) (1) (1) (1)	**4**
14(b)	Use of $s = ut$ $s = 9.7 \times 10^{16}$ (m) <u>Example of calculation</u> $s = 3.00 \times 10^8$ m s^{-1} $\times 10.3 \times (365 \times 86400)$ s$=9.74 \times 10^{16}$ m	(1) (1)	**2**
	Total for question 14		**6**

Question Number	Answer	Mark
15(a)	Use of $E_k = \frac{1}{2}mv^2$ (1) Use of $E = mc\Delta\theta$ (1) Use of efficiency= $\frac{\text{useful energy output}}{\text{total energy input}}$ (1) Required energy = 1.9 $\times 10^4$ J **Or** temperature rise = 29 K **Or** number of hits = 850 (1) Conclusion based on calculated values of energy transfer (1) **Or** Conclusion based on calculated value of temperature rise **Or** Conclusion based on calculated value of number of hits [conclusion must include a comparison of appropriate data] <u>Example of calculation</u> $E_k = \frac{1}{2} \times 1.1\text{ kg} \times (7.5\text{ m s}^{-1})^2 = 30.9\text{ J}$ $E = 1000 \times 30.9\text{ J} \times 0.72 = 2.23 \times 10^4\text{ J}$ $E = (1.1 + 0.45)\text{ kg} \times 490\text{ J kg}^{-1}\text{ K}^{-1} \times 25\text{ K} = 1.90 \times 10^4\text{ J}$ [If mass of hammer neglected, $E = 0.45\text{ kg} \times 490\text{ J kg}^{-1}$ $\text{K}^{-1} \times 25\text{ K} = 5.51 \times 10^3\text{ J}$	**5**
15(b)	No thermal energy is transferred (from the steel plate) to surroundings **Or** hammer comes to rest after hitting the steel plate (1) [Allow no energy is used to deform the steel]	1
	Total for question 15	**6**

Question Number	Answer		Mark
16(a)	Use of $\omega = \frac{2\pi}{T}$	(1)	
	Use of $v = r\omega$	(1)	
	$v = 1.02 \times 10^3$ m s^{-1}	(1)	**3**
	<u>Example of calculation</u> $\omega = \dfrac{2\pi}{27.3 \times 86400 \text{ s}} = 2.66 \times 10^{-6}$ rad s^{-1} $v = 3.84 \times 10^8 \text{ m} \times 2.66 \times 10^{-6} \text{ rad s}^{-1} = 1023 \text{ m s}^{-1}$		
16(b)(i)	$\Delta E_{grav} = mg\Delta h$ is appropriate for situations in which g is approximately constant	(1)	
	As the distance moved is only a small fraction of the distance to the Earth, the value of g hardly changes	(1)	**2**
16(b)(ii)	Use of $g = \frac{GM}{r^2}$	(1)	
	Use of $\Delta E_{grav} = mg\Delta h$	(1)	
	$\Delta E_{grav} = 7.6 \times 10^{19}$ J	(1)	
	OR		
	Use of $V_{grav} = -\frac{GM}{r}$	(1)	
	Recognises that $\Delta E_{grav} = m \times \Delta V_{grav}$	(1)	
	$\Delta E_{grav} = 7.6 \times 10^{19}$ J	(1)	**3**
	<u>Example of calculation</u> $g = \dfrac{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 6.02 \times 10^{24} \text{ kg}}{(3.84 \times 10^8 \text{ m})^2} = 2.72 \times 10^{-3} \text{ N kg}^{-1}$ $\Delta E_{grav} = 7.35 \times 10^{22} \text{kg} \times 2.72 \times 10^{-3} \text{N kg}^{-1} \times 0.38 \text{ m} = 7.61 \times 10^{19} \text{ J}$		
	Total for question 16		**8**

Question Number	Answer	Mark
*17	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 Gravitational forces act on objects with mass

IC2 But electric fields exert forces on objects with charge

IC3 Electric forces can be attractive or repulsive, but gravitational forces are always attractive
Or electric potential can be positive or negative, but gravitational potential is always negative.

IC4 Both fields have an infinite range
Or both fields are an example of “action at a distance”

IC5 Both the gravitational field around a point mass and the electric field around a point charge obey an inverse square law

IC6 The interaction between unit charges is larger than the interaction between unit masses (at a given separation)
Or the electric force between point charges is larger than the gravitational force between unit masses (at a given separation).

[for 2 linkage marks there must be at least 1 similarity and 1 difference]

Mark: **6**

	Total for question 17	**6**

Question Number	Answer		Mark
18(a)(i)	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	Use of $\Delta E = c^2 \Delta m$	(1)	
	$\frac{\Delta m}{\Delta t} = 5.04 \times 10^9$ (kg s^{-1})	(1)	**3**
	<u>Example of calculation</u>		
	$\frac{\Delta m}{\Delta t} = \frac{4.54 \times 10^{26}\text{ W}}{(3.00 \times 10^8\text{ m})^2} = 5.04 \times 10^9\text{ kg s}^{-1}$		
18(a)(ii)	Use of 0.08 %	(1)	
	Use of $\frac{\Delta m}{\Delta t}$ from (a)	(1)	
	t = 9.9×10^9 years (ecf from (i))	(1)	**3**
	<u>Example of calculation</u>		
	$\Delta m = \frac{0.08}{100} \times 1.97 \times 10^{30}\text{ kg} = 1.576 \times 10^{27}$		
	$t = \frac{1.576 \times 10^{27}\text{ kg}}{5.04 \times 10^9\text{ kg s}^{-1}} = 3.13 \times 10^{17}\text{ s} = 9.90 \times 10^9\text{ years}$		
18(b)	(Gamma Pavonis is more massive so) there is a greater temperature (and pressure) in the core	(1)	
	Rate of fusion is (much) higher than in delta Pavonis	(1)	
	Hence the time spent on main sequence is less and the suggestion is incorrect	(1)	**3**
	MP3 dependent on MP2		
	Total for question 18		**9**

Question Number	Answer		Mark
19(a)(i)	Use of $\Delta F = k\Delta x$ with $F = mg$ k = 213 (N m^{-1}) Example of calculation $k = \frac{mg}{\Delta x} = \frac{65.0 \text{ kg} \times 9.81 \text{ N kg}^{-1}}{(48.0 - 45.0) \text{ m}} = 212.6 \text{ N m}^{-1}$	(1) (1)	**2**
19(a)(ii)	(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**
19(a)(iii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ with $f = \frac{1}{T}$ f = 0.27 (Hz) Example of calculation $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{210 \text{ N m}^{-1}}{75 \text{ kg}}} = 0.266 \text{ Hz}$	(1) (1)	**2**
19(a)(iv)	Use of $\omega = 2\pi f$ Use of $a = -\omega^2 x$ a = 3.4 m s^{-2} (ecf from (iii)) Example of calculation $\omega = 2\pi \times 0.266 \text{ s}^{-1} = 1.67 \text{ rad s}^{-1}$ $a = (1.67 \text{ rad s}^{-1})^2 \times 1.2 \text{ m} = 3.35 \text{ m s}^{-2}$	(1) (1) (1)	**3**
19(b)	Work is done against air resistance **Or** air resistance causes damping So energy is transferred to the surroundings Amplitude decreases to zero	(1) (1) (1)	**3**
	Total for question 19		**12**

Question Number	Answer		Mark
20(a)	Top line correct Bottom line correct $^{210}_{82}\mathrm{Pb} \rightarrow {}^{210}_{83}\mathrm{Bi} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_e$	**(1)** **(1)**	**2**
20(b)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ Use of $\frac{\Delta N}{\Delta t} = (-)\lambda N$ Use of $A = A_0 e^{-\lambda t}$ Activity is 25 Bq after 1.87 years, so claim is false. <u>Example of calculation:</u> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{372 \times 86\,400\ \mathrm{s}} = 2.16 \times 10^{-8}\ \mathrm{s}^{-1}$ $\frac{\Delta N}{\Delta t} = \lambda N = 2.16 \times 10^{-8}\ \mathrm{s}^{-1} \times 4.15 \times 10^{9} = 89.6\ \mathrm{Bq}$ $25 = 89.6 \times e^{-2.16\times10^{-8}\,t}$ $-2.16 \times 10^{-8}\ \mathrm{s}^{-1} \times t = \ln\left(\frac{25\ \mathrm{Bq}}{89.6\ \mathrm{Bq}}\right)$ $t = \frac{-1.28}{-2.16\times10^{-8}\ \mathrm{s}^{-1}} = 5.91 \times 10^{7}\ \mathrm{s} = 1.87$ year	**(1)** **(1)** **(1)** **(1)**	**4**
20(c)	One pair of readings taken from graph and Rx^2 calculated 2 more pairs of readings taken from graph and Rx^2 calculated Check if Rx^2 is constant and conclusion consistent with calculations <u>Example of calculation</u>	**(1)** **(1)** **(1)**	**3**

R / s^{-1}	x / cm	Rx^2 / cm^2 s^{-1}
150.0	20.0	60000
45.0	40.0	72000
22.5	60.0	81000
15.0	80.0	96000

Question Number	Answer		Mark
20(d)	The tracks are thick indicating a heavily ionizing radiation The tracks are straight indicating that the radiations are massive **Or** the tracks are all about the same length so all the radiations have the same energy Therefore the tracks are made by radiation from an alpha source [dependent on MP1 or MP2]	**(1)** **(1)** **(1)**	**3**
	Total for question 20		**12**

Question Number	Answer		Mark
21(a)	Use of $\lambda_{\max}T = 2.898 \times 10^{-3}$ m K	(1)	
	T = 5800 (K)	(1)	**2**
	<u>Example of calculation</u>		
	$T = \dfrac{2.898 \times 10^{-3}\ \text{m K}}{5.0 \times 10^{-7}\ \text{m}} = 5796$ K		
21(b)	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)	
	$r = 7.0 \times 10^8$ m (ecf from (a))	(1)	**4**
	<u>Example of calculation</u>		
	$L = 590\ \text{W m}^{-2} \times 4\pi \times (2.3 \times 10^{11}\ \text{m})^2 = 3.92 \times 10^{26}$ W		
	$A = \dfrac{3.92 \times 10^{26}\ \text{W}}{5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4} \times (5800\ \text{K})^4} = 6.11 \times 10^{18}\ \text{m}^2$		
	$r = \sqrt{\dfrac{6.11 \times 10^{18}\ \text{m}^2}{4\pi}} = 6.97 \times 10^8$ m		
21(c)	Use of 22%	(1)	
	Use of efficiency = $\dfrac{\text{useful energy output}}{\text{total energy input}}$	(1)	
	Use of $I = P/A$ with $A = \pi r^2$	(1)	
	P = 1030 W (1.03 kW) so the power requirement is met.	(1)	**4**
	<u>Example of calculation</u>		
	$I = 0.78 \times 590\ \text{W m}^{-2} = 460\ \text{W m}^{-2}$		
	$A = \pi \times (1.1\ \text{m})^2 = 3.8\ \text{m}^2$		
	$P = 0.295 \times 460\ \text{W m}^{-2} \times 3.8\ \text{m}^2 \times 2 = 1030$ W		
	Total for question 21		**10**