Pearson Edexcel

Mark Scheme (Results)

October 2021

Pearson Edexcel International Advanced Subsidiary Level in Physics
(WPH15) Paper 01
Thermodynamics, Radiation, Oscillations and Cosmology

Question Number	Answer	Mark
1	**C is the correct answer** A, B, D are incorrect as C is the definition of a standard candle.	**(1)**
2	**B is the correct answer** A is not the correct answer as it is true to say that he electric force between the nuclei is repulsive. C is not the correct answer as it is true to say that the gravitational force and the electric force both increase. D is not the correct answer as it is true to say that the gravitational force between the nuclei is attractive.	**(1)**
3	**D is the correct answer** A, B, C are incorrect as $T = 2\pi\sqrt{\frac{\ell}{g}}$ and $g_{\mathrm{moon}} = \frac{g_{\mathrm{Earth}}}{6}$	**(1)**
4	**D is the correct answer** A is not the correct answer as alpha radiation would not penetrate the body B is not the correct answer as alpha radiation is not very penetrating C is not the correct answer as gamma radiation is not very ionising	**(1)**
5	**C is the correct answer** A is incorrect as the frequency has been substituted for the period B is incorrect as period has been substituted for frequency and the half amplitude value used D incorrect as half amplitude has been substituted	**(1)**
6	**C is the correct answer** A, B and D re incorrect as $\lambda = \frac{\ln 2}{t_{½}}$ and this has been substituted incorrectly in the expression $\frac{\Delta \mathrm{N}}{\Delta t} = (-)\lambda N$	**(1)**
7	**D is the correct answer** A is incorrect as this is the binding energy per nucleon of ^{3}He B is incorrect as this is the energy required to remove a single nucleon C is incorrect as this is the energy required to remove 2 nucleons	**(1)**
8	**D is the correct answer** A is incorrect as stars do not evolve along the main sequence B is incorrect as white dwarf stars do not evolve into main sequence stars C is incorrect as stars do not evolve along the main sequence	**(1)**
9	**D is the correct answer** A is incorrect as mass of stars increases along the main sequences B is incorrect as on an HR-diagram the temperature scale is an reverse scale C is incorrect as white dwarfs have smaller masses than main sequence stars	**(1)**
10	**D is the correct answer** A, B and C are incorrect because $T = \frac{2\pi}{\omega}$ and $\omega = \sqrt{\frac{a}{x}}$	**(1)**

Question Number	Answer	Mark
11	Use of $I = \frac{L}{4\pi d^2}$ (1) $d = 8.1 \times 10^{16}$ m (1) <u>Example of calculation</u> $d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{8.94 \times 10^{27}\ \text{W}}{4\pi \times 1.09 \times 10^{-7}\ \text{W m}^{-2}}} = 8.08 \times 10^{16}$ m	**2**
	Total for question 11	**2**

Question Number	Answer		Mark
12	Use of $\Delta E = mc\Delta\theta$ Use of $P = \frac{\Delta E}{\Delta t}$ Use of $\Delta E = mL$ m = 0.189 kg <u>Example of calculation</u> $P = \frac{0.855\text{ kg} \times 4190\text{ J kg}^{-1}\text{ K}^{-1} \times (100 - 21.5)\text{ K}}{115\text{ s}} = 2.45 \times 10^3\text{ W}$ $2.45 \times 10^3\text{W} \times 175\text{ s} = m \times 2.26 \times 10^6\text{ J kg}^{-1}$ $\therefore m = \frac{2.45 \times 10^3\text{W} \times 175\text{ s}}{2.26 \times 10^6\text{ J kg}^{-1}} = 0.189\text{ kg}$	(1) (1) (1) (1)	**4**
	Total for question 12		**4**

Question Number	Answer		Mark
13(a)	Mass difference calculated	(1)	
	Conversion from u to kg	(1)	
	Use of $\Delta E = c^2 \Delta m$	(1)	
	ΔE = 5.53 (MeV)	(1)	**4**
	For full marks to be awarded some working should be shown – a bald answer scores zero. "Some working" must include at least two of the steps to the answer.		
	<u>Example of calculation</u>		
	Mass difference = (228.02873 - 224.02021 - 4.00260) u = 5.92×10^{-3} u		
	Mass difference = 5.92×10^{-3} u × 1.66×10^{-27} kg u^{-1} = 9.83×10^{-30} kg		
	$\Delta E = \left(3.00 \times 10^8 \text{ m s}^{-1}\right)^2 \times 9.83 \times 10^{-30} \text{ kg} = 8.85 \times 10^{-13} \text{ J}$		
	$\Delta E = \dfrac{8.85 \times 10^{-13} \text{J}}{1.60 \times 10^{-13} \text{J MeV}^{-1}} = 5.53 \text{ MeV}$		
13(b)	(Mathematical) statement of momentum conservation	(1)	
	Use of $E_\text{k} = \frac{p^2}{2m}$ **Or** use of $E_\text{k} = \frac{1}{2}mv^2$ and $p = mv$	(1)	
	(Mathematical) statement of energy conservation	(1)	
	E_k=5.4 MeV and statement is correct	(1)	**4**
	<u>Example of calculation</u> $p_\alpha = -p_\text{Ra}$		
	$2m_\alpha \ E_\alpha = \ 2m_{Ra} \ E_{Ra}$		
	$E_{Ra} = \dfrac{m_\alpha}{m_{Ra}} \times E_\alpha$		
	$E_\alpha + E_{Ra} = 5.5 \text{ MeV}$		
	$E_\alpha + \dfrac{m_\alpha}{m_{Ra}} \times E_\alpha = 5.5 \text{ MeV}$		
	$E_\alpha = \dfrac{m_{Ra}}{m_{Ra} + m_\alpha} \times 5.5 \text{ MeV}$		
	So $E_\text{k} = \frac{224}{228} \times 5.53 \text{ MeV} = 5.43 \text{ MeV}$		
	Total for question 13		**8**

Question Number	Answer		Mark
14(a)	Use of $pV = NkT$	**(1)**	
	Temperature conversion	**(1)**	
	$N = 6.02 \times 10^{23}$	**(1)**	**3**
	<u>Example of calculation</u>		
	$N = \frac{pV}{kT} = \frac{1.01 \times 10^5 \text{ Pa} \times 0.0241 \text{ m}^3}{1.38 \times 10^{-23} \text{J K}^{-1} \times (20.0 + 273) \text{ K}} = 6.02 \times 10^{23}$		
14(b)	Use of $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$	**(1)**	
	Use of 60.5 %	**(1)**	
	Ratio = 2.7 (Do not award MP3 if a value for either mass has been assumed)	**(1)**	**3**
	<u>Example of calculation</u>		
	$\frac{1}{2}m_1\langle {c_1}^2 \rangle = \frac{1}{2}m_2\langle {c_2}^2 \rangle$		
	$\therefore \frac{m_1}{m_2} = \frac{\langle {c_2}^2 \rangle}{\langle {c_1}^2 \rangle}$		
	$\frac{\langle {c_C}^2 \rangle}{\langle {c_m}^2 \rangle} = 0.605^2 = 0.366$		
	$\frac{m_c}{m_m} = \frac{\langle {c_m}^2 \rangle}{\langle {c_C}^2 \rangle} = \frac{1}{0.366} = 2.73$		
	Total for question 14		**6**

Question Number	Answer		Mark
*15	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

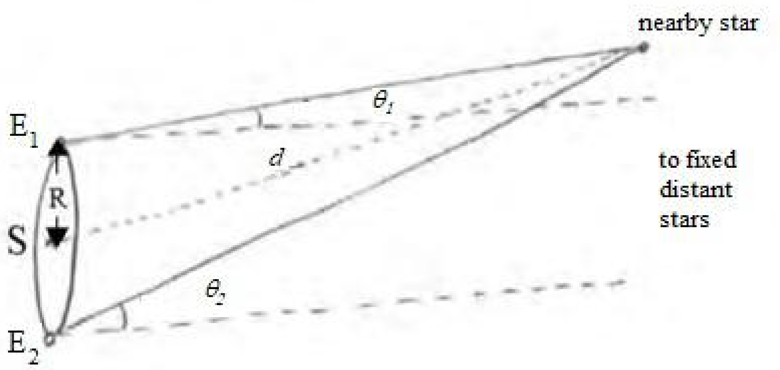
Indicative content

IC1 There is a very high temperature (in the core) **(1)**
IC2 (So) nuclei/protons have a high kinetic energy **(1)**
IC3 (Sufficient) to overcome electrostatic repulsion **(1)**
IC4 And allow nuclei/protons to get close enough to fuse **(1)**
IC5 Gravitational forces produce a very high density (in the core) **(1)**
IC6 (So) the collision rate is high enough to sustain fusion **(1)**

Mark: **6**

	Total for question 15	**6**

Question Number	Answer		Mark
16(a)	<table><tr><th>H_α / nm</th><th>Point</th></tr><tr><td>656.2837</td><td>B</td></tr><tr><td>656.2797</td><td>C</td></tr><tr><td>656.2757</td><td>A</td></tr></table>	**(1)**	**1**
16(b)	**MAX 2 from:** Light from the edge of the Sun moving toward the Earth is received with a shorter wavelength [Accept "point A" for "edge moving toward the Earth" and "blue shift" for "shorter wavelength"] Light from the edge of the Sun moving away from the Earth is received with a longer wavelength [Accept "point B" for "edge moving away from the Earth" and "red shift" for "longer wavelength"] There is a variation in the relative velocity between the Earth and different points on the Sun's surface [Can be awarded if A and B incorrectly linked to change in wavelength] [Reference to Doppler effect can score max 1]	 **(1)** **(1)** **(1)**	**2**
16(c)	Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with λ = 656.2797 nm Use of $v = \frac{2\pi r}{T}$ to calculate T Conversion of T into days. T = 27.8 days which is approximately 28 days **OR** Conversion of T = 28 days into seconds Use of $v = \frac{2\pi r}{T}$ to calculate v [1820 m s^{-1}] Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with λ = 656.2797 nm v = 1830 m s^{-1} which is approximately 1820 m s^{-1} **OR** Conversion of T = 28 days into seconds Use of $v = \frac{2\pi r}{T}$ to calculate v [1820 m s^{-1}] Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with λ = 656.2797 nm to calculate $\Delta\lambda$ $\Delta\lambda = 3.98 \times 10^{-3}$ m which is approximately 4.0×10^{-3} m Full credit for other approaches e.g. comparison of calculated value of v/c from T = 28 days and calculated value of v/c from $\frac{\Delta\lambda}{\lambda}$ <u>Example of calculation</u> $v = c \times \frac{\Delta\lambda}{\lambda} = 3.00 \times 10^8 \text{ m s}^{-1} \times \frac{(656.2837 - 656.2797)\text{ nm}}{656.2797\text{ nm}} = 1828 \text{ m s}^{-1}$ $T = \frac{2\pi r}{v} = \frac{2\pi \times 7.0 \times 10^8 \text{ m}}{1828 \text{ m s}^{-1}} = 2.41 \times 10^6 \text{ s}$ $T = \frac{2.41 \times 10^6 \text{ s}}{86400 \text{ s day}^{-1}} = 27.8 \text{ days}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 16		**7**

Question Number	Answer		Mark
17(a)	Find (angular) displacement of the star (as Earth moves around the Sun) over a 6 month period **Or** find (angular) displacement of the star (as Earth moves around the Sun) over a diameter of the Earth's orbit	**(1)**	
	Measurements are made against the background of (more) distant stars	**(1)**	
	Radius/diameter of the Earth's orbit about the Sun must be known/measured (to calculate the distance to the star)	**(1)**	**3**
	[For full credit, it must be clear that angles are being measured]		
	[Marks can be obtained from an annotated diagram]		
			
	[Accept the symmetrical diagram seen in many textbooks]		
17(b)	**EITHER**		
	Distant galaxies are receding	**(1)**	
	The velocity of recession can be calculated from the redshift	**(1)**	
	A graph of recessional velocity against distance has a gradient equal to the Hubble constant H_0	**(1)**	
	The age of the universe is $1/H_0$	**(1)**	
	OR		
	Distant galaxies are receding	**(1)**	
	The redshift can be calculated	**(1)**	
	A graph of redshift against distance has a gradient equal to H_0/c	**(1)**	
	The age of the universe is $1/H_0$	**(1)**	**4**
	Total for question 17		**7**

Question Number	Answer		Mark
18(a)(i)	Use of $\Delta F = k\Delta x$ k = 346 (N m^{-1}) <u>Example of calculation</u> $k = \frac{15.0 \text{ kg} \times 9.81 \text{ m s}^{-2}}{0.425 \text{ m}} = 346.2 \text{ N m}^{-1}$	**(1)** **(1)**	**2**
18(a)(ii)	(When the cradle is displaced): 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**
18(a)(iii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ T = 1.1 s <u>Example of calculation</u> $T = 2\pi\sqrt{\frac{(7.25+2.55) \text{ kg}}{350 \text{ N m}^{-1}}} = 1.05 \text{ s}$	**(1)** **(1)**	**2**
18(b)	The maximum load the spring can support when oscillating is less than the maximum load the spring supports when in equilibrium. As when the mass is below the equilibrium position the force exerted on the spring is greater than the force at equilibrium.	**(1)** **(1)**	**2**
	Total for question 18		**8**

Question Number	Answer	Mark
19(a)(i)	Top line correct **(1)** Bottom line correct **(1)** <u>Example of calculation</u> $^{60}_{27}Co \rightarrow ^{60}_{28}Ni + ^{0}_{-1}\beta^{-} + ^{0}_{0}\overline{\nu}_{e}$	**2**
19(a)(ii)	The mass of the Ni nucleus is much larger than total mass of the other two particles **(1)**	**1**
19(b)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ **(1)** Use of $A = A_0 e^{-\lambda t}$ **(1)** t = 6.0 (years) **(1)** <u>Example of calculation</u> $\lambda = \frac{\ln 2}{5.27 \times 3.16 \times 10^{7}\ s} = 4.16 \times 10^{-9}\ s^{-1}$ $1.85 \times 10^{14} Bq = 4.07 \times 10^{14}\ Bq\ e^{-4.16 \times 10^{-9} \times t}$ $\therefore t = \frac{\ln\left(\frac{4.07 \times 10^{14}\ Bq}{1.85 \times 10^{14}\ Bq}\right)}{4.16 \times 10^{-9}\ s^{-1}} = 1.886 \times 10^{8}\ s$ $\therefore t = \frac{1.894 \times 10^{8}\ s}{3.16 \times 10^{7}\ s\ year^{-1}} = 5.996$ years	**3**
19(c)	Required % transmission calculated **(1)** Distance *x* read from graph for required transmission **(1)** *x* =1.1 cm, so shielding would be insufficient **(1)** **OR** Required % transmission calculated **(1)** % transmission read from graph for 1.0 cm shielding **(1)** % transmission ≈ 33%, so shielding would be insufficient **(1)** <u>Example of calculation</u> Required % transmission $\leq \frac{1.2 \times 10^{14}\ Bq}{4.0 \times 10^{14}\ Bq} \times 100\% = 30\ \%$ From graph, for required % transmission thickness of shielding = 1.1 cm,	**3**
	Total for question 19	**9**

Question Number	Answer		Mark
20(a)	A main sequence star is fusing hydrogen (into helium) in the core of the star	**(1)**	**1**
20(b)(i)	Use of $L = A\sigma T^4$ **and** $A = 4\pi r^2$ $r = 6.94 \times 10^8$ (m) <u>Example of calculation</u> $r = \sqrt{\frac{L}{4\pi\sigma T^4}} = \sqrt{\frac{3.83 \times 10^{26}\text{ W}}{4\pi \times 5.67 \times 10^{-8}\text{ W m}^{-2}\text{ K}^{-4}\ (5780\text{ K})^4}} = 6.94 \times 10^8\text{ m}$	**(1)** **(1)**	**2**
20(b)(ii)	Use of $L = A\sigma T^4$ **and** $A = 4\pi r^2$ Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $\lambda_{max} = 9.8 \times 10^{-7}$ (m) (ecf value of r from (i)) <u>Example of calculation</u> $T = \sqrt[4]{\frac{L}{4\pi r^2\sigma}} = \sqrt[4]{\frac{1600 \times 3.83 \times 10^{26}\text{ W}}{4\pi\,(150 \times 7.0 \times 10^8\text{ m})^2 \times 5.67 \times 10^{-8}\text{ W m}^{-2}\text{ K}^{-4}}}$ $= 2972$ K $\lambda_{max} = \frac{2.898 \times 10^{-3}\text{ m K}}{2972\text{ K}} = 9.75 \times 10^{-7}$ m	**(1)** **(1)** **(1)**	**3**
20(b)(iii)	λ_{max} is not in the wavelength range for red light **Or** λ_{max} is in the infrared wavelength range There is a range of wavelengths emitted around the value of λ_{max} The most intense region of the visible spectrum will be red light (dependent upon MP2) [Accept annotated sketches of the black body curve]	**(1)** **(1)** **(1)**	**3**
20(c)	(The mass of the Sun decreases and so) the gravitational force exerted on the planet decreases The gravitational force provides a centripetal force $F = m\omega^2 r$, ω decreases and so T must increase **OR** (The mass of the Sun decreases and so) the gravitational force exerted on the planet decreases The gravitational force provides a centripetal force $F = \frac{mv^2}{r}$, v will decrease and so T must increase **OR** Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ Derive expression for T Deduce that T will increase	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
	Total for question 20		**12**

Question Number	Answer		Mark
21(a)(i)	Use of $V_{grav} = -\frac{GM}{r}$ $V_{grav} = (-)\ 5.53 \times 10^{7}$ (J kg^{-1}) Example of calculation $V_{grav} = -\frac{6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 5.98 \times 10^{24}\text{ kg}}{(6.36 \times 10^{6} + 8.5 \times 10^{5})\text{ m}} = -5.532 \times 10^{7}\text{ J kg}^{-1}$	**(1)** **(1)**	**2**
21(a)(ii)	Use of $\Delta V \times m$ $\Delta E_{grav} = 3.7 \times 10^{10}$ J Example of calculation $\Delta E_{grav} = (-5.53 - (-6.27)) \times 10^{7}\text{ J kg}^{-1} \times 4990\text{ kg} = 3.69 \times 10^{10}\text{ J}$	**(1)** **(1)**	**2**
21(b)	Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ Substitute for ω using $\omega = \frac{2\pi}{T}$ Use of $T^2 = \frac{4\pi^2 r^3}{GM}$ T = 6090 s **Or** T = 1.69 hours Number of orbits in 1 day = 14.2, so claim is not valid **OR** Equate $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ Substitute for v using $v = \frac{2\pi r}{T}$ Use of $T^2 = \frac{4\pi^2 r^3}{GM}$ T = 6090 s **Or** T = 1.69 hours Number of orbits in 1 day = 14.2, so claim is not valid Example of calculation $\frac{GMm}{r^2} = m\omega^2 r$ $\therefore T = 2\pi \times \sqrt{\frac{r^3}{GM}} = 2\pi \times \sqrt{\frac{(6.36 \times 10^{6}\text{ m} + 8.5 \times 10^{5}\text{ m})^3}{6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 5.98 \times 10^{24}\text{ kg}}} = 6091\text{ s}$ $\therefore T = \frac{6090\text{ s}}{(60 \times 60)\text{ s hour}^{-1}} = 1.69\text{ hours}$ Number of orbits in 1 day $= \frac{24\text{ hours}}{1.69\text{ hours}} = 14.2$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**5**

21(c)	Advantage: satellite can cover more of the Earth's surface **Or** satellite passes close to the polar regions **(1)** **Or** better resolution, as satellite closer to the Earth Disadvantage: satellite has to be tracked in the sky **Or** satellite data cannot be received continuously **(1)** **Or** cannot provide continuous viewing of a single location	**2**
	Total for question 21	**11**