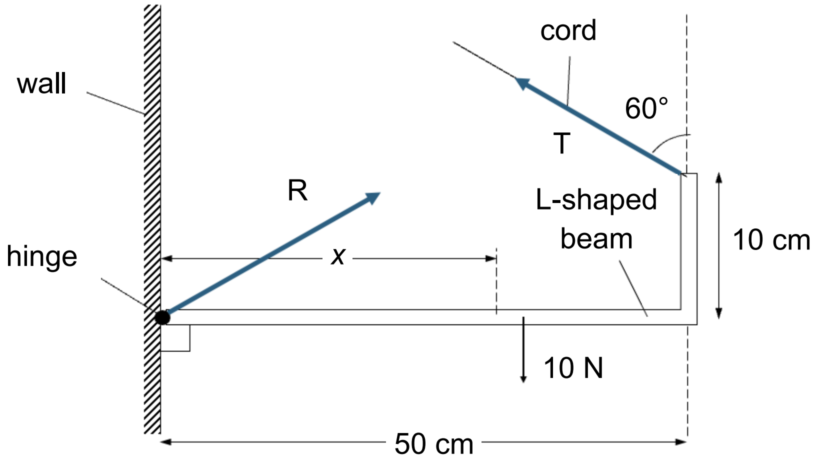
2024 JC2 Prelim Exam H2 Physics Paper 2 Solution

1	**(a)**	**(i)**	Distance $=$ area under the $v-t$ graph $=\frac{1}{2}(8.8)(0.90)=4.0\text{ m}$	**B1**
		(ii)	average acceleration $=\frac{\text{change in velocity}}{\text{time}}$ $=\frac{(-4.4-8.8)}{0.50}$ $=-26\text{ m s}^{-2}$ *(Circle but not penalise for missing -ve sign)*	**C1** **A1**
	(b)	**(i)**	The accelerations are the same as the gradients of the graph before and after the rebound are the same. (the girl is in a state of free fall before and after the rebound).	**B1**
		(ii)	The area under the lines represents height and the second area is smaller than the first area, hence, the rebound height is less than the initial height. Thus the GPE of the girl at t = 0 is larger than the GPE at t = 1.85 s. **OR** The kinetic energy (KE) of the girl at trampoline equals to the GPE at maximum height. The speed after rebound is smaller and hence the KE becomes smaller. Thus the gravitational potential of the girl after rebound is less.	**M1** **A1** **(M1)** **(A1)**

2	**(a)**		Using hinge as pivot: Clockwise moment due to weight = anti-clockwise moment due to tension Moment due to $T_y = T(\cos 60)50$ Moment due to $T_x = T(\sin 60)10$ $Wx = T(\cos 60)50 + T(\sin 60)10$ $10x = 5.0[50(\cos 60) + 10(\sin 60)]$ $x = 16.8 = 17\text{ cm}$ Note: if either moment vertical/horizontal is not considered, max 1 mark.	**M1** **A1**

	(b)	(i)	 Both vectors drawn and labelled 3 forces have common point	B1 B1
	(b)	(ii)	$R_x = T_x = 5.0\sin 60 = 4.33$ N $R_y + T_y = W$ $R_y = W - T_y = 10 - 5.0\cos 60 = 7.5$ N $\lvert R\rvert = \sqrt{R_x^2 + R_y^2} = \sqrt{4.33^2 + (-7.5)^2}$ $= 8.7$ N	M1 M1 A0

3	(a)	(i)	$GPE_{final} = -\dfrac{GM_{earth}(80)}{6.4\times10^6 + (1.5\times10^3)\times10^3}$ Total energy on Earth's surface = total energy at LEO $KE_i + GPE_i +$ energy supplied $= KE_f + GPE_f$ $\left(-\dfrac{GM_{earth}(80)}{6.4\times10^6}\right) + 3.0\times10^9 = KE_f + \left(-\dfrac{GM_{earth}(80)}{6.4\times10^6 + (1.5\times10^3)\times10^3}\right)$ $KE_f = 3.0\times10^9 + (6.67\times10^{-11})(6.0\times10^{24})(80)\left(\dfrac{1}{7.9\times10^6} - \dfrac{1}{6.4\times10^6}\right)$ $KE_f = 2.1\times10^9$ J	C1 C1 A1
		(ii)	<u>Centripetal force is provided by gravitational force</u> $F_c = F_G$ $F_C = \dfrac{GMm}{r^2}$ $F_c = \dfrac{6.67\times10^{-11}(6.0\times10^{24})(80)}{(7.9\times10^6)^2}$ $F_c = 510$ N (1m for both working and answer.)	B1 B1
	(b)	(i)	Gravitational potential at a point is the <u>work done per unit mass by external agent</u> in bringing a small test mass <u>from infinity to that point</u>.	B1

		(ii)	Since $F=-m\dfrac{d\phi}{dr}$, the negative of the gradient of the ϕ-r graph gives the force. Positive gradient means gravitational force (vector) is negative Since gravitational force is negative when displacement is positive, it is in the opposite direction as the displacement from Earth and hence is attractive. **OR** Potential decreases nearer to the Earth. Gravitational force must always be in direction of decreasing potential and points towards Earth and is attractive. **OR** The gravitational potential is always negative, so the external force points in the opposite direction to displacement from infinity to that point / points away from the earth. Hence, the gravitational force points opposite to the external force towards the earth and is an attractive one.	**M1** **A1** **(M1)** **(A1)** **(M1)** **(A1)**
		(ii)	$KE_{initial}+U_{initial}=KE_{final}+U_{final}$ $\frac{1}{2}mu^2+m\phi_{initial}=\frac{1}{2}mv^2+m\phi_{final}$ $\frac{1}{2}u^2+\left(-6.25\times10^7\right)=0+0$ $u=11.2$ km s^{-1}	 **M1** **A1**

4	**(a)**	**(i)1**	distance moved by wavefront/wave during one period / during one oscillation of a particle in that wave **OR** minimum distance between two wavefronts/crests/troughs/peaks **OR** minimum distance between two points which are in phase	**B1** **(B1)** **(B1)**
		(i)2	The phase difference between two particles refers to how much one particle lags or leads another with respect to a cycle. **OR** how one wave lags or leads another wave of the same wavelength.	**B1** **(B1)**
		(ii)	$\dfrac{\Delta\theta}{2\pi}=\dfrac{\Delta x}{\lambda}$ OR $\dfrac{\Delta\theta}{360°}=\dfrac{\Delta x}{\lambda}$	**B1**
	(b)	**(i)**	Using $v=\dfrac{\lambda}{T}$ or $v=f\lambda$ and $f=\dfrac{1}{T}$ From Fig. 4.1, T = 0.60 s $\lambda=vT=(20)(0.60)$ $=12$ cm	 **M1** **A1**
	(b)	**(i)**	$\dfrac{\Delta\theta}{360°}=\dfrac{\Delta t}{T}=\dfrac{0.20}{0.60}$ $\Delta\theta=120°$ (or $360°-120°=240°$) (Award M1 mark only if answers expressed in radians (2.09 rad).)	**M1** **A1**

		(ii)	At t = 0.45 s, using the principle of superposition, $\text{net displacement} = 1.00 + (-3.00)$ $= -2.00 \text{ mm}$ (Accept ±0.1mm)	**M1** **A1**
		(iv)	Intensity $\propto$ (amplitude)^2 $\frac{I_Q}{I_P} = \left(\frac{A_Q}{A_P}\right)^2 = \left(\frac{2.0}{3.0}\right)^2$ $= 0.444 \ (3\text{sf})$	**M1** **A1**
		(v)	Two sources (waves) are said to be coherent when the phase difference is always the same OR there is a constant phase relationship at all times.	**B1**

5	**(a)**	Current = 2.7 – 1.5 = 1.2 A	**B1**
	(b)	p.d. across XY = 12 V = 1.5 (5.0 + R) Resistance R = 3.0 Ω	**B1**
	(c)	p.d. across XZ = (1.6/2.0)12 = 9.6 V p.d. across XW = 1.5(5.0) = 7.5 V potential difference = 9.6 – 7.5 = 2.1	**C1** **A1**
	(d)	When the resistance of the variable resistor is now increased, the effective resistance of the circuit increases. For the same e.m.f. supply, the power dissipated in the effective resistor decreases since power is inversely proportional to the effective resistance. Thus the power supplied by the battery decreases. **OR** When the resistance of the variable resistor is now increased, the effective resistance of the 5.0 ohm and variable resistor increases, so the current in the variable resistor decreases. The current in the resistance wire is unchanged since the p.d. across the wire and the resistance remain the same. So, the current in the battery decreases (same e.m.f.) the power decreases.	**B1** **B1** **B1** **(B1)** **(B1)** **(B1)**

6	**(a)**		$B_{max} = \frac{\mu_0 I_{max}}{2\pi d}$ $= \frac{(4\pi \times 10^{-7})(1.2)}{(2\pi)(20 \times 10^{-2})}$ $= 1.2 \times 10^{-6} \text{ T } (2\text{sf})$	**C1** **A1**
	(b)	**(i)**	$\Phi_{max} = NB_{max}A = NB(\pi r^2)$ $= 1500(1.2 \times 10^{-6})\pi(0.50 \times 10^{-2})^2$ $= 1.41 \times 10^{-7} \text{ Wb } (3\text{sf})$	**C1** **A1**

		(ii)	The alternating current in the cable induces an alternating (changing) magnetic field at the plastic ring / toroidal solenoid. This cuts the solenoid and thus there is an alternating (changing) magnetic flux linkage at the solenoid. Hence, by Faraday's law of electromagnetic induction, e.m.f. is induced in the solenoid.	**B1** **B1**
		(iii)	The root-mean-square e.m.f. of the alternating voltage source is the equivalent to the value of steady direct current e.m.f. that dissipates the same power as the average amount of power dissipated by the alternating voltage. *(subtract 1m if average is not mentioned)*	**B1** **B1**

7	**(a)**		$\frac{hc}{\lambda} = E_3 - E_2$ (identifying which two levels.) **OR** Uses wavelength of 658 nm $\frac{6.63\times10^{-34}\times3.00\times10^{8}}{658\times10^{-9}} = E_3 - (-3.40\times1.60\times10^{-19})$ $E_3 = -2.42\times10^{-19}$ J	**C1** **(C1)** **C1** **A1**
	(b)	**(i)**	Energy of each photon, $E = \frac{hc}{\lambda} = 2.84\times10^{-19}$ $\text{Power} = \text{intensity}\times\text{area}$ $\left(\frac{N}{t}\right)E = \text{intensity}\times\text{area}$ $\left(\frac{N}{t}\right) = \frac{\text{intensity}\times\text{area}}{E}$ number per unit time, $\frac{N}{t} = \frac{(160)(2.5\times10^{-6})}{2.84\times10^{-19}}$ $= 1.4\times10^{15}\ \text{s}^{-1}$	**C1** **M1** **A0**
		(ii)	$\text{Pressure} = \frac{\text{force}}{\text{area}}$ Pressure on the mirror by the light beam is equal to the total force of impact by the photons per unit area. Change of momentum for one photon after 'reflected' = 2p (where p = momentum of the photon) Total force exerted = Comboned rate of change of momentum $= 2\left(\frac{N}{t}\right)p = 2\left(\frac{N}{t}\right)\left(\frac{h}{\lambda}\right)$ $= 2\left(1.4\times10^{15}\right)\left(\frac{6.63\times10^{-34}}{7.0\times10^{-7}}\right)\left(= 2.65\times10^{-12}\right)$ $\text{Pressure} = \frac{2.65\times10^{-12}}{2.5\times10^{-6}}$ $= 1.1\times10^{-6}$ Pa	**C1** **C1** **A1**

		(iii)	For the same intensity, replacing the beam of red light with blue light that has a smaller wavelength will result in a decrease of $\frac{N}{t}$ ($\frac{N}{t}$ proportional to λ). Pressure is proportional to $\frac{N}{t}$ and inversely proportional to λ. Thus the pressure remains the **same**.	**M1** **A1**

8	**(a)**	**(i)**	Let the power of the sun by P_{sun}. Considering the sun as a point source, the energy spreads out uniformly through space and the intensity is given by $\text{intensity} = \frac{P_{sun}}{4\pi r^2}$ $P_{sun} = 1400 \times \left[4\pi\left(150\times10^9\right)^2\right]$ $= 4.0\times10^{26}$ W	**M1** **M1** **A0**
		(ii)	$\text{Unit of power} = \frac{\text{unit of work done}}{\text{unit of time}} = \frac{\text{kg m}^2\text{ s}^{-2}}{\text{s}}$ $= \text{kg m}^2\text{ s}^{-3}$ $\text{Unit of }\left(\sigma A T^4\right) = \left(\text{kg s}^{-3}\text{ K}^{-4}\right)\left(\text{m}^2\right)\left(\text{K}^4\right)$ $= \text{kg m}^2\text{ s}^{-3}$ Since the unit of P is the same as the unit of $\sigma A T^4$, the equation is homogeneous.	 **B1** **B1** **A0**
		(iii)	$P = \sigma A T^4$ $4.0\times10^{26} = \left(5.7\times10^{-8}\right)\left[4\pi\left(109\times6.37\times10^6\right)^2\right]T^4$ $T = 5830$ K	**C1** **A1**
	(b)	**(i)**	Maximum speed is related to the maximum temperature Maximum temperature = 15×10^6 K Considering the protons to behave as ideal gases, $\text{KE of each proton} = \frac{3}{2}kT$ $\frac{1}{2}m_{proton}v^2 = \frac{3}{2}kT$ $\frac{1}{2}\left(1.67\times10^{-27}\right)v^2 = \frac{3}{2}\left(1.38\times10^{-23}\right)\left(15\times10^6\right)$ $v = 6.1\times10^5\text{ m s}^{-1}$	 **C1** **A1**
		(ii)	As the proton approaches each other, their initial kinetic energies equal the electric potential energy at the closest distance. By conservation of energy, $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r} = 2\times\frac{1}{2}m_{proton}v^2$ $\frac{\left(1.6\times10^{-19}\right)\left(1.6\times10^{-19}\right)}{4\pi\left(8.85\times10^{-12}\right)r} = 2\times\frac{1}{2}\left(1.67\times10^{-27}\right)\left(6.1\times10^5\right)^2$ $r = 3.7\times10^{-13}$ m	 **C1** **A1**

		(iii)	The radius of nucleus is of the order of 10^{-15} m. The closest distance is much larger than the radius of the proton and thus the two protons will be too far apart for fusion to take place.	**B1** **B1**
		(iv)	When protons are very close to each other, the uncertainty in their position Δx is small. According to the Heisenberg Uncertainty Principle, this results in a larger uncertainty in their momentum. Thus, the large uncertainty in momentum Δp means that there is a significant probability that some protons have much higher momentum (and thus kinetic energy) than the average to overcome the Coulomb barrier in those instances, allowing fusion reaction to take place.	**B1** **B1**
	(c)	**(i)**	Mass difference = 4(1.007276u) – 4.002603u = 0.026501u Energy release = Δmc^2 = (0.026501) (1.66×10^{-27}) (3.0×10^{9})^2 = 3.96×10^{-12} J	**C1** **A1**
		(ii)	Energy release by 0.70% of the mass = (0.70/100)(4)(1.007276) (1.66×10^{-27})(3.0×10^{8})^2 = 4.21×10^{-12} J Since the two values can be rounded to 4×10^{-12} J , the two values are close to each other and the statement is valid. **OR** Percentage difference = ($4.21 \times 10^{-12} - 3.96 \times 10^{-12}$)/($3.96 \times 10^{-12}$) = 6.3% Since the percentage difference between the two values is less than 10%, the statement is valid.	**M1** **A1** **(M1)** **(A1)**
	(d)	**(i)**	$\gamma = \frac{\sqrt{2m(U-E)}}{\hbar} = \frac{\sqrt{2(1.67\times10^{-27})(10^{-13}-10^{-16})}}{6.63\times10^{-34}/2\pi} = 1.731\times10^{14}$ $P \approx e^{-2\gamma d} = e^{-2(1.731\times10^{14})(1.8\times10^{-13})}$ = 8.6×10^{-28}	**C1** **A1**
		(ii)	The vast number of protons in the Sun of the order of more than 10^{38} suggests some protons will be able to tunnel through the potential barrier for fusion to occur.	**B1**