JC2 HCI H2 Physics Prelim Paper 2 Suggested Solutions

1	a)		Net force acting on the body is zero in all directions Net torque /moment acting on the body about any point is zero	B1 B1
	b)		Two smooth spheres M_1 and M_2, both of mass 2.0 kg, are connected by an inextensible bar of negligible mass to form a rigid body. The spheres rest on smooth 45° inclines as shown in Fig. 1.1.	
		(i)		

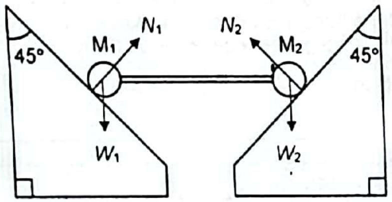


Fig. 1.1

			correct identification of forces correct orientation of forces (marker please decide)	B1 B1
		(ii)	$N\cos 45° = 2(9.81)$ $N = 27.7$ N	M1 A1
	(c)	(i)	Yes. The horizontal components of N1 and N2 must be equal in magnitude (so that horizontal net force is zero).	B0 B1
		(ii)	Consider moments about the intersection of N_1 and N_3. The clockwise moment produced by $4g$ is larger than the anti-clockwise moment produced by $2g$. OR Consider the lines of action of N_1, N_3 and $6g$. Since the C.G. lies closer to M_3 than M_1, the lines of action will not intersect at one point.	B1 B1

		(iii)		[1]

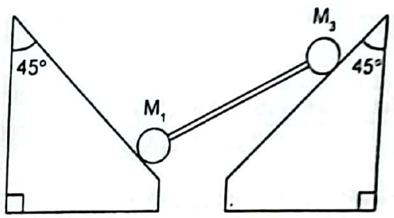


Fig. 1.2

2(a)		The **gravitational field strength** ***g*** at a point is the *gravitational force per unit mass* acting on a small test point mass placed at the point.	[1]
(b)	(i)	Acceleration of the satellite = g at that point = $\frac{GM_E}{r^2}$	[1]
	(ii)	The gravitational force on satellite by Earth provides for the required centripetal force to keep the satellite in circular orbit. $\frac{GM_E m}{r^2} = mr\omega^2$ ω – angular velocity	[1]
		Since $T = \frac{2\pi}{\omega}$, $\frac{GM_E m}{r^2} = mr(\frac{2\pi}{T})^2$ $T^2 = \frac{4\pi^2 r^3}{GM_E}$	[1]
		$T^2 \propto r^3$ (Shown) and constant of proportionality is $\frac{4\pi^2}{GM_E}$	[1]
	(iii)	Period for geostationary satellite, T = 24 h = 24 x 60 x 60 s = 86400 s	[1]

		Angular velocity, $\omega = \frac{2\pi}{T}$ = 7.3 x 10^{-5} rad s^{-1}	
	(iv)	$r^3 = \frac{GM_E}{\omega^2} = \frac{(6.67\times10^{-11})(6.0\times10^{24})}{(7.3\times10^{-5})^2}$	[1]
		$r = (7.51\times10^{22})^{1/3}$ = 4.22 x 10^7 m	[1]
		Thus, altitude = $r - R_E$ = 3.6 x 10^7 m	[1]
	(v)	One possible use is for communication purpose to a particular region on Earth where there is a line of sight to the satellite. The geostationary satellite is always at a fixed position above the Earth and this ensure an uninterrupted communication channel with the satellite. Or For monitoring / spying a particular region on Earth below the satellite as the geostationary satellite is always at a fixed position above the Earth.	[2]

3	(a)		At the equilibrium point, $F_{res} = 0 \rightarrow kx - mg = 0$ $kx = mg \rightarrow k = \frac{mg}{x}$, where x is the extension of spring. Any of these points or other correct points from the graph: When a mass of 150 g is hung, the extension on the spring is 10.0 cm. When a mass of 300 g is hung, the extension is 20.0 cm. When a mass of 450 g is hung, the extension is 30.0 cm $k = \frac{0.150g}{0.100} = 14.7$ N m^{-1}.	M1 M1 A0
	(b)	(i)	$\omega = 2\pi f \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{14.715}{0.450}} = 0.91$ Hz	M1 A1
		(ii)	$\Delta GPE = Mg(extension) = 0.450\times9.81\times0.300 = 1.32435$ J $\Delta EPE = \frac{1}{2}k(e_2^2 - e_1^2) = \frac{1}{2}(14.715)(0.400^2 - 0.100^2) = 1.103625$ J $\Delta KE = 1.32435 - 1.103625 = 0.220725$ J $0.220725 = \frac{1}{2}mv^2 \rightarrow v = 0.990$ m s^{-1} OR Note that question is asking for v for an oscillation with amplitude 20.0 cm at displacement of 10.0 cm. $v = \omega\sqrt{x_0^2 - x^2} = 2\pi(0.91)\sqrt{0.200^2 - 0.100^2}$	M1 M1 M1 A1
	(c)		The effective mass of the spring-mass system increases. The resonant frequency of heavier masses is at lower values of frequencies (or at greater periods). Hence, the frequency of the oscillation would be reduced. OR use $\omega = 2\pi f \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, deduce that f is inversely proportional to $\sqrt{m}$. When m increases, f is reduced.	M1 A1

4	(a)		Diffraction is the spreading of waves (into their "geometrical shadows"), after passing through small apertures or round obstacles. Destructive interference is when two waves superpose/meet/overlap completely out of phase, resulting in a wave of zero (or reduced) amplitude.	B1 B1 B1 [3]
	(b)	(i)	$d\sin 90° \geq n\lambda$ $n \leq \frac{d}{\lambda} = \left(\frac{10^{-2}}{1000}\right)\left(\frac{f}{c}\right) = \left(\frac{10^{-2}}{3000}\right)\left(\frac{4.69\times10^{14}}{3.00\times10^{8}}\right) = 5.2$ $n = 5$ (correct d - 1, correct λ - 1) The possible number of maxima = 5 + 5 + 1 = 11	[2] [1]
		(ii)	$\sin\theta = \frac{n\lambda}{d} = n\left(\frac{3000}{10^{-2}}\right)\left(\frac{c}{f}\right) = 5\left(\frac{3000}{10^{-2}}\right)\left(\frac{3.00\times10^{8}}{4.69\times10^{14}}\right)$ $\theta = 73.6°$ $\tan 73.6° = \frac{x}{2.30}$ $x = 2.30\tan 73.6° = 7.83$ m	[1] [1]
	(c)		$\sin\theta = \frac{n\lambda}{d}$ As green light has shorter wavelength, λ is decreased then sin θ also decreases. This means the separation between maxima will be closer.	[1]
	(d)		The diffraction grating causes sharper, brighter maxima, which spread out a lot more than a double slit. The bigger angle and better visibility give more accurate data to calculate the wavelength.	[1]

5a) $KE_{max} = eV_s$

$= (1.60\times10^{-19})(1.15)$

$= 1.84\times10^{-19}$ J

b) $\frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{370\times10^{-9}}$

$= 5.38\times10^{-19}$ J

c) $KE_{max} = \frac{hc}{\lambda} - \Phi$

$1.84\times10^{-19} = 5.38\times10^{-19} - \Phi$

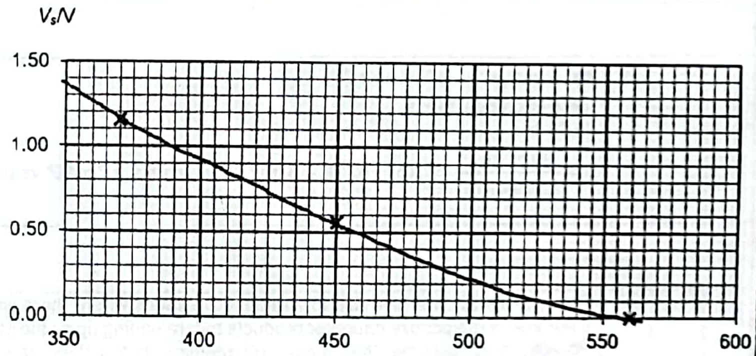
$\Phi = 3.54\times10^{-19}$ J

$\frac{hc}{\lambda_0} = \Phi$

$\frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda_0} = 3.54\times10^{-19}$

$\lambda_0 = 562$ nm

d)



B1 for (560, 0.00)

B1 for $\frac{1}{x}$ curve

e) There is no effect.
Doubling the intensity will double the rate of arrival of photons on the metal surface, but the energy of individual photon remains unchanged.

6	(a)	(i)	Isotopes are atoms that have the same number of protons but different number of neutrons.	[1]
		(ii)	As the half-life of X (in years) is very long, the measured activity of sample X is thus relatively constant.	[1]
		(iii) 1	Decay constant of Y, $\lambda_Y = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{1.5 \times 60 \times 60}$ = 1.283 x 10^{-4} s^{-1}	[1]
		2	Equilibrium is reached when the rate of production of Y (from the decay of X) is equal to its rate of decay. Hence, the number of isotope Y in the sample will stabilise at a constant value.	[1]
		3	Thus, the activity of Y is about 1.1 x 10^7 Bq. Amount of Y, $N_Y = \frac{A_Y}{\lambda_Y} = \frac{1.1\times10^7}{1.283\times10^{-4}}$ = 8.6 x 10^{10} atoms	[1] [1]
	(c)	(i)	By $N = N_o e^{-\lambda t}$: $5N = 6Ne^{-\lambda t}$ Take ln on both sides, $\ln 5 = \ln 6 - \lambda t$ $t = \frac{\ln 6 - \ln 5}{1.570\times10^{-18}} = 1.161\times10^{17}$s = 3.682 x 10^9 years = 3.7 x 10^9 years	[1] [1]
		(ii)	Decay of Th-232 will give rise to a radioactive series where there will be a number of radioactive daughter products before ending up as the stable Pb-208. It is assume that these intermediate radioactive daughter products have very short half-life (much shorter than that of Th-232) so the number of intermediate daughter products are insignificant compared to Th-232 and Pb-208.	[1]
		(iii)	If the assumption is not valid, the current amount of decay products will be more than 1N. The fraction of undecayed Th-232 is actually less than $\frac{5}{6}$, thus answer for (b)(i) will be an under-estimate.	[1]

7 (a)	'per unit mass' is missing	[1]
(bi)	A turkey of twice the mass will have twice the volume. Since $V \alpha L^3$, $L \alpha \sqrt[3]{V}$ and so if volume is doubled L will increase by a factor of $\sqrt[3]{2}$ = 1.2599 Since $A \alpha L^2$, A will increase by a factor of $(\sqrt[3]{2})^2$ = 1.5873	[2]
(bii)	22 × 1.26 = 27.7 cm	[1]
(biii)	0.46/1.59 = 0.29 m^2	[1]
(ci)	$E = mc\Delta t = 9 \times 3200 \times 90 = 2.59MJ$	[2]
(cii)	$P = \frac{E}{t} = \frac{2590000}{2200} = 1200s$	[1]
(ciii)	Vast majority of heat is lost. Heat is lost to surroundings/ endothermic chemical reactions/change of state of water.	[2]

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(d)		Mass ×2 Surface area ×1/1.5873 Width ×1.2599 Scale factor is therefore given by 2× 1/1.5873 × 1.2599 = 1.59	[2]
(e)	(i)	Half width of 9 Kg turkey = 0.277/2 = 0.1385 m Area of 9 kg turkey = 0.46÷2=0.23 m^2 $\frac{\Delta Q}{\Delta t} = 0.6 \times 0.23 \times \frac{140}{0.1385} = 139W$	[3]
	(ii)	$t = \frac{E}{P} = \frac{2590000}{139} = 18633s = 5.18hours$	[1]
	(iii)	Since 18.0 kg turkey is double the mass of the 9.0 kg turkey the cooking time will increase by the same factor as before i.e. 1.59. Hence cooking time = 5.18×1.59 = 8.24 hours.	[1]
	(iv)	S. I units are W m^{-1} °C^{-1} Base units are kg m s^{-3} °C^{-1}	[2]