2023 JC2 H2 Prelim Paper 3 Solutions

1 **(a)** The electric field lines, along which the electric forces exerted by the charged sphere on other charges act, are always perpendicular to the surface of the sphere (i.e. the electric field lines are radial). M1

Hence the field lines appear to originate from the centre of the sphere. A0

(b) **(i)** arrow pointing to the left labelled 'electric force' (F_E) **and** arrow pointing downwards labelled 'weight'(W) C1

(ii) 1.
Electric force on the particle
$F_E = QE$
$F_E = VQ / d$
$= (2.0 \times 10^2 \times 8.0 \times 10^{-19}) / 4.0 \times 10^{-2} = 4.0 \times 10^{-15}$ N A1

resultant force $= \sqrt{\left(3.9\times10^{-15}\right)^2 + \left(4.0\times10^{-15}\right)^2} = 5.6\times10^{-15}\,N$ C1 A1

2. let θ be the angle to horizontal
$\tan\theta$ = weight /electric force
$\theta = \tan^{-1}(3.9 \times 10^{-15} / 4.0 \times 10^{-15})$
$= 44°$ A1

Substitution must be shown

(c) **(i)** downward sloping line from (0, 2.0) M1
magnitude of gradient of line increases with time and line ends at (T, 0) A1

(ii) Horizontally:
$s = ½ at^2$
$2.0 \times 10^{-2} = ½ (4.0 \times 10^{-15} / (3.9 \times 10^{-15} / 9.81)\, T^2$ C1
$T = 0.063$ s A1

2 **(a)** **(i)** gravitational field strength is equal to the negative gravitational potential gradient B1
Or state equation $g = - d\phi/dr$

(b) **(i)** $G = GM/r^2$ C1
$g_A = G(3M)/(2R)^2 = ¾\ GM/R^2$
$g_B = G(M)/(R)^2 = GM/R^2$
so conclude $g_A < g_B$ A1

alternative soln:
by calculating the gradient at surface and using gradient = field strength
deduce gradient at surface of A < gradient at surface of B

(ii) M is the point/position in which net gravitational field strength is zero B1

(iii) sketch: one curve, starting with gradient of decreasing magnitude at 2R and finishing with gradient of increasing magnitude at D – R B1
field strength shown as zero near the point of maximum potential (position of M correct), with gravitation field strength at surface of A< B B1

(c) **(i)** The gravitational force of attraction between the stars are of the same magnitude. This force provides the centripetal force for each star to orbit about their common centre of mass. B1

(ii) There is no external force acting on the binary stars, so the c.m. should not change position. B1

(iii) centripetal force = $M_A d\omega^2 = M_B(2.8 \times 10^8 - d)\omega^2$ C1

Or $M_A d_A = M_B d_B$

$M_A / M_B = 3.0 = (2.8 \times 10^8 - d) / d$

$d = 7.0 \times 10^7$ km A1

3 **(a)** **(i)** Molecules collide with one another in a haphazard manner hence they possess different kinetic energies at any time. B1

(word "random" does not get marks in answer)

(ii) No intermolecular forces in ideal gas, hence no potential energy B1

(Do not accept specific forces eg. "attraction"; vague description eg. "interaction"

(iii) $p = 1/3\ \rho <c^2>$ M1

=> $pV = 1/3\ M <c^2>$ since $\rho = M/V$

For ideal gas, $pV = n RT$

Hence, $1/3\ M <c^2> = n RT$ B1

Total KE = $½ M <c^2> = 3/2\ n RT$

(Must start with "Use the equation" given, other methods not accepted)

(iv) Low pressure B2

High temperature

(Low pressure implies molecules are far apart, high temperature implies high KE)

(b) **(i)** pV = nRT M1

$(6.0 \times 10^5) (0.10) = (10) (8.31)$ T A1

T = 722 K

(ii) The products of p and V are not constant eg. the product of p and V is 5.0×10^4 J at B, but 6.0×10^4 J at A. B1

(or calculate temperature at B = 600 K, lower than 722 K at A)

(iii) Work done in one cycle estimated from the area ABC enclosed M1

= 8.8×10^4 J A1

(Note positive sign since net work is done by the gas
Do not accept area "under curve")

(iv) In one cycle $\Delta U = q + W = 0$ => q = 8.8 × 10^4 J A1

(working or otherwise clear explanation required)

4 (a) (i) 1 cycle

$T = 1.90$ ms C1

$$f = \frac{1}{T} = \frac{1}{\left(1.90 \times 10^{-3}\right)} = 526.3 = 526 \text{ Hz}$$ A1

(Students are allowed to use one or more cycles.)

(ii)

$$\phi = \frac{\Delta t}{T} \times 2\pi$$ C1

$$\frac{4}{5}\pi = \frac{\Delta t}{T} \times 2\pi$$

$$\Delta t = \left(\frac{4\pi}{5}\right)\left(\frac{T}{2\pi}\right) = \frac{2}{5}(1.90) = 0.76 \text{ ms}$$

$$1.50 + 0.76 = 2.26 \text{ ms}$$ A1

(iii)

$$I = \frac{P}{4\pi r^2} \quad \Rightarrow \quad I \propto \frac{P}{r^2}$$

$$\frac{I_1}{I} = \frac{P_1}{r_1^2} \times \frac{r^2}{P}$$

for $I_1 = I$

$$r_1^2 = \frac{P_1}{P} r^2$$ C1

$$r_1 = \sqrt{\frac{0.25P}{P}} r = \sqrt{0.25}(120) = 60 \text{ cm}$$ A1

(b) (i) All the particles in a progressive wave <u>oscillate with the same amplitude</u>. The particles in a stationary wave oscillate with <u>amplitudes that range from zero at the nodes to a maximum at the antinodes</u>. B1

(ii) All the particles <u>within a wavelength</u> of a progressive wave <u>have different phases</u>. B1

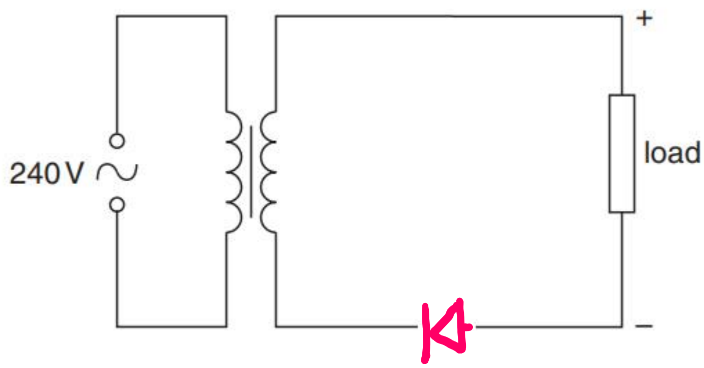
All the particles <u>between two adjacent nodes</u> of a stationary wave <u>have the same phase</u>. Particles in <u>adjacent segments have a phase difference of π radians</u>.

5	**(a)**	**(i)**	waves at (each) slit/aperture spread	B1
			hence wave(s) able to superpose/meet/interfere in overlap region	B1
		(ii)	Unable to achieve constant phase difference/coherence for two separate light source(s)	B1
			or	
			to ensure waves/light from the double slit are coherent/have constant phase difference	
		(iii)	Greater intensity of bright fringes	B1
			Narrower bright fringes	B1
	(b)		$x = \lambda D / a$	C1
			$\lambda = (36 \times 10^{-3} \times 0.48 \times 10^{-3}) / (16 \times 2.4)$	C1
			$= 4.5 \times 10^{-7}$ m	A1
	(c)	**(i)**	water is flat/still/no disturbance	B1
			destructive interference as the path difference is 2.5λ when sources start in phase	B1
	(c)	**(ii)**	1. surface/water/P vibrates/oscillates with max amplitude waves from the two dippers arrive in phase	B1
			2. surface/water/P vibrates/oscillates as a non-zero minima due to incomplete destructive interference	B1

6 **(a)(i)** Iron core prevent flux losses or improve flux linkage B1

(a)(ii) Primary a.c. current causes changing flux in iron core B1
e.m.f. / current (induced) in core
induced/eddy current in core causes (joule)heating B1

(b)(i) diode correctly drawn to give polarity across load. B1



(b)(ii) $\frac{N_s}{N_p} = \frac{V_s}{V_p}$ C1

C1

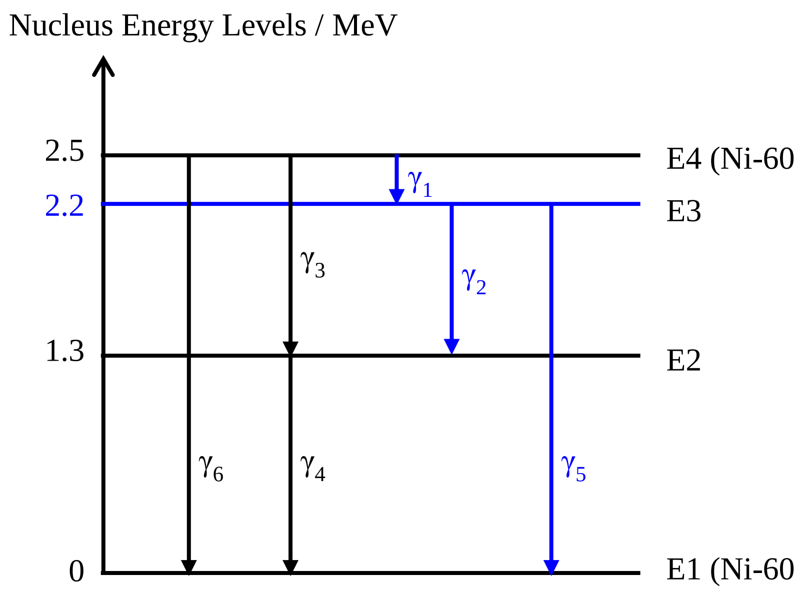
$V_0 = \sqrt{2} \times V_{rms} = \sqrt{2} \times 240$

ratio = 9.0 / ($\sqrt{2} \times 240$) A1
= 1/38 or 0.027

(b)(iii) V_{rms} = 9.0/2 = 4.5 V C1
Mean power output = $V_{rms}^2/R = (4.5)^2/4.5$
= 4.5 W A1

7	**(a)**		Magnetic flux density - force per unit current per unit length when conductor is placed perpendicular to the magnetic field	B2
			magnetic flux – product of area and magnetic flux density normal to the area	B1
	(b)		$\Phi = BA \sin\theta$	B1
	(c)	**(i)**	$\Phi = 1.8 \times 52 \times 10^{-2} \times 95 \times 10^{-2} \sin 90^{o}$	C1
			$= 0.89$ Wb	A1
		(ii)	As frame rotates, there is a rate of change of magnetic flux/cutting of flux,	B1
			By Faraday's law, (induced) e.m.f. is proportional to rate of change/cutting of (magnetic) flux (linkage)	B1
		(iii)	Sides PS and QR(both correct)	B1
		(iv)1	greatest rate of change of flux occurs when $\theta = 0°, 180^{o}$ and 360 or when plane of frame is parallel to field, so induced emf is maximum	B1
				B1
			least rate of change of flux occurs when $\theta = 90°$ and 270^{o} or when plane of frame is perpendicular to field, so induced emf is zero	B1
			Magnitude of e.m.f. determined by rate of change of flux	
		(iv)2	Since flux $\phi = BA \sin \theta = BA \sin\omega t$ which is sinusoidal	B1
			Induced emf $= d\phi/dt = BA\omega \cos \omega t$ is also sinusoidal	B1
		(iv)3	Max e.m.f. $= BA\omega = 0.89 \times 4\pi$	C1
			$= 11.2$ V	A1
		(iv)4	r.m.s current $= I_o/\sqrt{2} = (11.2/4.8)/\sqrt{2}z$	C1
			$= 1.646$ A	A1
			At slower angular speed, Rate of change of flux (linkage/cutting)	B1
			less peaks would be smaller amplitude Or maximum e.m.f. smaller.	B1

8	**(a)**	**(i)**	${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e} + \gamma$ [B1] for e. [B1] for the other 2.	B1 B1
		(ii)	Number of nuclei in 1 g of C0-60 $= \frac{1}{60} \times 6.02 \times 10^{23}$ $= 1.003 \times 10^{22}$ $A = \lambda N$ $= \frac{\ln 2}{5.272 \times 265 \times 24 \times 60 \times 60} 1.003 \times 10^{22}$ $= 4.182 \times 10^{13}$ Bq Correction: 365 days	C1 C1 A1
	(b)	**(i)**	A discrete packet of energy of electromagnetic radiation (energy > 100 keV OR wavelength < 10 pm.)	B1 B1
		(ii)	When the nucleus de-excites from a higher to lower energy level, a gamma photon of energy equal to the energy transition is emitted. Since photon energy in Fig 8.1 is discrete, the difference in energy levels and hence the energy levels of the nucleus themselves must be discrete.	B1 B1

<table>
<tr><td></td><td></td><td>(iii)</td><td>1.

</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Energy of E3 = 2.2 MeV
E3 labelled and draw to scale on diagram</td><td>B1
B1</td></tr>
<tr><td></td><td></td><td></td><td>2. The 3 transitions giving rise to γ_1, γ_2 and γ_5 drawn correctly

-1 for any incorrect transition</td><td>B2</td></tr>
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<tr><td></td><td></td><td></td><td>3.
$\Delta E = \Delta m.c^2$
$(2.5 \times 10^{-6})(1.60 \times 10^{-19}) = \Delta m.(3.00 \times 10^{8})^2$
$\Delta m = 4.444 \times 10^{-30}$ kg
$= 0.0002677$ u
Correction: 0.002677 u
At excited state, mass = rest mass + Δm
= 55.93079+0.0002677
= 59.93347 u</td><td>C2

A1</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>Sudden deceleration of beta-particles due to collision with lead target results in k.e. lost.
K.e. lost is converted to X-ray photons</td><td>B1

B1</td></tr>
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		(ii)	Energy of photon = total kinetic energy lost of beta-particle $$\frac{hc}{\lambda_{\text{min}}} = E_{\beta}$$ $$\frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda_{\text{min}}} = (0.30\times10^{6})(1.60\times10^{-19})$$ $$\lambda_{\text{min}} = 4.14\times10^{-12}\ \text{m}$$	C1 A1