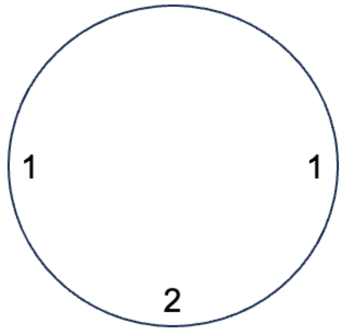
2023 YIJC JC2 H2 Preliminary Examination Paper 3 Suggested Solutions

1	**(a)**		The principle of conservation of momentum states that total momentum of the system remains constant provided that there is no net/resultant force exerted on the system	 **B1** **B1**
	(b)	**(i)**	Since no net external force, total momentum along AB remains constant. Total initial momentum along AB = Total final momentum along AB 4.0 (4.2 cos θ) + 2.8 (6.0 cos θ) = (4.0 + 2.8)(3.7) 33.6 cos θ = 25.16 θ = 41.5°	 **C1** **A1**
		(ii)	Impulse = change in momentum Considering direction perpendicular to line AB Impulse = final momentum – initial momentum = 0 – 4.0 (4.2 sin 41.5°) = – 11.1 N s (accept positive value)	 **C1** **A1**
		(iii)	Since, the total final momentum along the direction perpendicular to AB (vertical) is zero, the total initial momentum along the direction perpendicular to AB (vertical) must equal to zero. Since both balls have the same initial momentum (16.8 kg m s^{-1}), the angles have to be the same, so that the total initial momentum along the direction perpendicular to AB equals to zero.	**B1** **B1**
		(iv)	Total KE before collision = ½ (4.0)(4.2)^2 + ½ (2.8)(6)^2 = 85.7 J Total KE after collision = ½ (4.0 + 2.8)(3.7)^2 = 46.5 J Since the KE is not conserved, the collision is inelastic.	**M1** **A1**
2	**(a)**	**(i)**	1. A gas consists of a very large number of molecules. 2. The molecules are in constant, random motion and obey Newton's laws of motion. 3. Collisions between gas molecules are elastic or the collision between gas molecules and the walls of the container are elastic. 4. Intermolecular forces act only during collisions between molecules. The duration of a collision is negligible compared with the time interval between collisions. 5. The volume of the gas molecules themselves is negligible compared with the volume occupied by the gas (this implies that almost all of the gas is empty space). ***Any 2 of the above***	**B1** **B1**

		(ii)	As volume compresses, the time between successive collisions of a molecule against the wall decreases or the frequency of the collisions of molecules against the wall increases. For same change in linear momentum, the net force acting on the wall increases, hence increasing pressure	**B1** **B1**
	(b)	**(i)**	$pV = nRT$ For A, $1.5 \times 10^5 \times 2.0 \times 10^{-3} = n \times 8.31 \times 200$ n = 0.18 mol	 **A1**
		(ii)	$E = \frac{1}{2}mc_{rms}^2 = \frac{3}{2}kT$ $\frac{1}{2} \times 40 \times 1.66 \times 10^{-27} \times c_{rms}^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times 200$ $c_{rms} = 353 \approx 350$ m s^{-1}	 **M1** **A1**
		(iii)	For C to D ΔU = Q + W $\frac{3}{2}(0.181)(8.31)(400 - 720) = -50 + W$ W = - 670 J Work is done by the gas	 **M1** **A1** **A1**
3	**(a)**	The periodic motion of an object about the equilibrium point in which its acceleration is proportional to the displacement of the object from the equilibrium point and always acts in the opposite direction to its displacement.		**B1**
	(b)	**(i)**	$\omega = 2\pi f = 2\pi(12) = 75$ rad s^{-1}	**C1**
		(ii)	Amplitude $x_0 = 32 / 2 = 16$ mm = 0.016 m $v_0 = \omega x_0 = (75.4)(0.016) = 1.2$ m s^{-1} Obtain zero mark if the first M1 mark is not obtained, ie using the incorrect amplitude.	**M1** **A1**
		(iii)	Maximum contact force at lowest point $F_{net} = N - W = m\omega^2 x_0$ $N = m\omega^2 x_0 + mg$ $= (0.025)(75.4^2)(0.016) + (0.025)(9.81)$ $= 2.5$ N	 **M1** **A1**

		(iv)	Front view of disc  1 mark each Note: just need to mark and label one of the "1"	**M2**

4	**(a)**	**(i)**	x = 18.0 cm	**A1**
		(ii)	$V_A + V_B = 0$ $\frac{3.6\times10^{-9}}{4\pi\varepsilon_0(0.180)}+\frac{q_B}{4\pi\varepsilon_0(0.120)}=0$ $q_B = -2.4\times10^{-9}$ C (use of $V_A = V_B$ giving 2.4×10^{-9} C scores one mark)	**C1** **C1** **A1**
	(b)		By conservation of energy, Total energy at x = 5.0 cm = total energy at x = 27.0 cm $e(560) + KE_A = e(-600) + KE_B$ (= 0 J) $KE_A = 1.9\times10^{-16}$ J $\frac{1}{2}mv^2 = 1.9\times10^{-16}$ J Speed of electron = 2.02×10^{7} m s^{-1}	**C1** **C1** **A1**
	(c)		The gradient gives the magnitude of the net E-field strength. Since force experienced equals to charge multiply with net E-field The largest force experienced is at x = 27.0 cm since the gradient is the largest.	**B1** **B1** **B1**

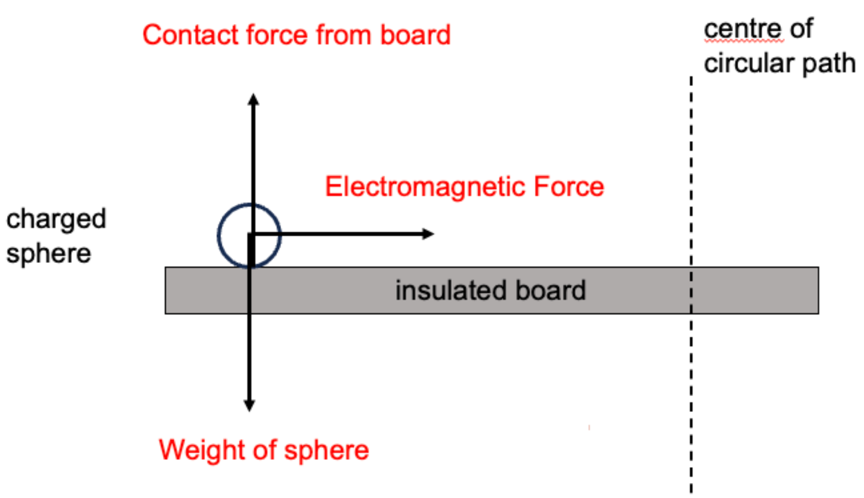
5	**(a)**	**(i)**		Total charge = $nALe$	**A1**
		(ii)		Current I = total charge / time $= nALe / t$ $= nAve$	 **M1** **A0**
	(b)			For each cross-section X and Y, $v = I / nAe$ Since $I_X = I_Y$ (series connection) and $n_X = n_Y$ (same material) $\dfrac{\text{average drift speed of free electrons at cross-section Y}}{\text{average drift speed of free electrons at cross-section X}} = \dfrac{A_X}{A_Y}$ $= \dfrac{\pi d^2 / 4}{\pi (0.69d)^2 / 4}$ $= 2.1$	 **C1** **A1**
	(c)	**(i)**		Resistance $= \dfrac{\rho L}{A}$ $= \dfrac{4\rho L}{\pi d^2}$ $= \dfrac{4(5.1 \text{ x } 10^{-7})(50 \text{ x } 10^{-2})}{\pi (0.36 \text{ x } 10^{-3})^2}$ $R_{AB} = 2.5\ \Omega$	 **M1** **A0**
		(ii)	**1.**	$L_{CD} = 2L_{AB}$, $d_{CD} = ½\ d_{AB}$, $\rho_{CD} = \rho_{AB}$ (same material) Hence, $R_{CD} = 8R_{AB} = 20\ \Omega$ $I_{AB} = E / (R_{AB} + R)$ $= 6.0 / (2.5 + 2.5)$ $= 1.2$ A $I_{CD} = E / R_{CD}$ $= 6.0 / 20$ $= 0.3$ A Hence, total current supplied by E = 1.2 + 0.3 = 1.5 A	 **C1** **C1** **A1**
			2.	Potential drop from A to M = $I_{AB}(0.5R_{AB})$ $= 1.2(1.25)$ $= 1.5$ V Potential drop from C to N = $I_{CD}(0.5\ R_{CD})$ $= 0.3(10)$ $= 3.0$ V Hence, p.d. between M and N = 1.5 V	 **M1** **A1**

6	(a)			$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$ Correct notation for alpha particle Total A number conserved and total Z number conserved	M1 A1
	(b)	(i)		Initial k.e. of the alpha particle $= 25 \times (5 \times 10^{3}) \times (5.2 \times 10^{-18})$ $= 6.5 \times 10^{-13}$ J Assumption: (1) All the initial kinetic energy of the alpha particle was used to produce ion-pairs. (2) No energy was used to excite molecules that the alpha particle encountered.	M1 B1
	(b)	(ii)	1.	$\frac{1}{2}(4 \times 1.66 \times 10^{-27})\, v^2 = 6.5 \times 10^{-13}$ $\therefore$ v = $1.399 \times 10^{7} \approx 1.4 \times 10^{7}$ m s^{-1}	M1 A1
	(b)	(i)	2.	By conservation of momentum, $0 = m_\alpha v_\alpha + m_{Th} v_{Th}$ $0 = (4u \times 1.399 \times 10^{7}) + (234u \times v_{Th})$ $v_{Th} = -2.39 \times 10^{5} \approx 2.4 \times 10^{5}$ m s^{-1} (speed)	M1 A1
	(c)	(i)		$\lambda = \frac{\ln 2}{t_{1/2}}$ $\lambda = \frac{0.693}{24.1 \times 24 \times 3600}$ $= 3.328 \times 10^{-7} \approx 3.3 \times 10^{-7}$ s^{-1}	M1 A1
	(c)	(ii)		$A = \lambda N$ $A = \lambda \times \left(\frac{m}{M_r} \times N_A\right)$ $= (3.33 \times 10^{-7}) \times (\frac{5}{234} \times 6.02 \times 10^{23})$ $= 4.28 \times 10^{15} \approx 4.3 \times 10^{15}$ Bq	M1 A1

7	(a)	(i)	1. The frequency of the source is the number of oscillations per unit time.	B1
			2. $n\lambda$	A1

		(ii)	Either	*Or*	
			$v = \frac{\text{distance}}{time} = \frac{n\lambda}{t}$	*f oscillation per unit time so fλ is the distance per unit time*	**M1**
			Since $f = \frac{n}{t}$, $v = f\lambda$	*distance per unit time is v so v = fλ*	**A1**
	(b)	**(i)**	The incident wave from the loudspeaker and the reflected wave from the hard surface superpose / interfere / overlap. Since the two waves have the same speed and frequency, a stationary sound wave is formed		**B1** **B1** **A0**
		(ii)	The positions of the three nodes and two antinodes are where the intensity are zero and maximum respectively.		**B1**
		(iii)	Node to node = ½ λ = 34 cm $v = f\lambda$ 330 = f × 0.68 f = 485 ≈ 490 Hz		**C1** **A1**
		(iv)	When x = 20 cm, Intensity = 0.925 I When x = 40 cm, Intensity = 0.25 I Since $I = kA^2$ $\frac{0.925I}{0.25I} = \frac{A_{x=20}{}^2}{A_{x=40}{}^2}$ $\frac{A_{x=20}}{A_{x=40}} = 1.92$		**C1** **C1** **A1**
	(c)	**(i)**	1. Each wavelength (of the white light) travels the same path difference or are in phase when reaching the zero order. All the wavelengths (of the white light) constructively interfere, producing a maximum. Hence the diffraction pattern has white light at the zero order		**B1** **B1** **A0**
			2. Since the wavelength of red light is longer than that of the blue light, the first order of red light is diffracted by a larger angle than that of the blue light since sin(θ) is proportional to the wavelength. Thus, the first order of red light is further from the zero order than the first order of blue light.		**B1** **B1**
		(ii)	$d \sin \theta = n \lambda$ $\frac{1}{N}\sin 61.0° = 2 \times 625 \times 10^{-9}$ $N = 7.00 \times 10^5$ line per m		**C1** **A1**

		(iii)	For the same angle as in **(ii)** $d \sin \theta = n\lambda = 2 \times 625 = 1250$ For n = 1, λ = 1250 (outside visible) For n = 3, λ = 417 (in visible) For n = 4, λ = 312.5 (outside visible) Another wavelength of the visible spectrum that gives a maximum is 420 nm.	**C1** **A1**

8	**(a)**	**(i)**	 1 mark per complete vector (with label)	**B3**
		(ii)	By Flemings left hand rule, vertically <u>downwards</u>	**B1**
		(iii)	Since centripetal acceleration is due to the electromagnetic force: $mr\omega^2 = Bqv = Bqr\omega$ $m\omega = Bq$ $m\frac{2\pi}{T} = Bq$ $T = \frac{2\pi m}{Bq}$ $T = \frac{2\pi(0.0060)}{0.5(5.0 \times 10^{-2})}$ $T = 1.5$ s	**M1** **M1** **A1**
		(iv)	With the electric field directed downwards, there is an <u>upward electric force</u>. <u>Hence the net vertical force is upwards.</u> Charged sphere experiences a upward acceleration concurrently with the centripetal acceleration. Charged particle starts to take <u>an upward helical path.</u>	**B1** **B1** **B1**

			Due to increasing upward velocity, the vertical distance between loops of the helical path increases.	
	(b)	**(i)**	Lenz's law of electromagnetic induction states that the direction of the induced e.m.f produced causes effect to oppose the change that produces it.	**B1**
		(ii)	As the rod slides across the rails, it will cut the magnetic flux. By Faraday's Law, there will be an e.m.f. induced. As the circuit is closed, there will be an induced current. OR As the rod rolls across the conducting rails, the area formed by the rod, rails and connecting wire is reduced. Hence there is a decrease in flux due to the decreasing area. By FL, there will be an induced e.m.f.. As the circuit is closed, there will be an induced current.	**B1** **B1**
		(iii)	Using Faraday's Law, $E = Blv\sin\theta$ $E = (8.00)(0.500)(2.0)\sin 90$ $E = 8.0\ \text{V}$ $I = \frac{E}{R} = \frac{8.0}{10.0}$ $I = 0.80\ \text{A}$	**M1** **A1**
		(iv)	By Fleming's left hand rule, the induced current in the rod and magnetic field results in a leftward EM force acting on the rod. This results in a net leftward force that decelerates the rod. The leftward EM force is dependent on the magnitude of induced current and therefore on the rod's velocity. Hence it decreases to zero as the rod slows down. Since the rod will come to a stop, there is no induced current thereafter and hence no leftward force. Therefore the rod will not gain leftward velocity. OR using energy concepts: The induced current in the rod and conducting rails requires energy for it to occur. This energy comes from the kinetic energy of the rod. Hence the rod loses KE and slows down. Once it comes to a complete stop, there is no more induced current.	**B1** **B1** **B1** **B1** **B1** **B1**
		(v)	F_{ext} = Leftward EM force on rod due to induced current $F_{ext} = BIL\sin\theta$ $F_{ext} = (8.00)(0.80)(0.500)\sin 90$ $F_{ext} = 3.2\ \text{N}$	**M1** **A1**