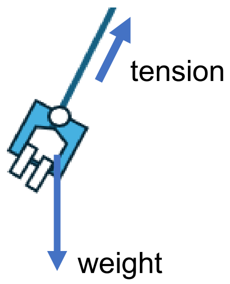
2024 JC2 Prelim Exam H2 Physics Paper 3 Solution

1	**(a)**	**(i)**	Because the speed at B is the same at C, the gain in KE is due to the loss of GPE from A to B only. Gain in KE in the end = Loss in GPE from A to B $\frac{1}{2}mv^2 = mgh$ $v = \sqrt{2gh} = \sqrt{2(9.81)(2.5)}$ $= 7.0 \text{ m s}^{-1}$	 **C1** **A1**
		(ii)	From A to B, the <u>gravitational potential energy drop is converted to kinetic energy</u> of the child. From B to C, <u>the further loss in gravitational potential energy is not converted into kinetic energy but dissipated as work done against contact friction</u> (or thermal energy and sound). Thus, the child's speed is unchanged.	**B1** **B1**
		(iii)	Work done against friction $= Fs$ $Fs = \text{loss of KE from C to D}$ $= KE_C - KE_D$ $F(7.6) = \frac{1}{2}(54)(7.0)^2 - 0$ $F = 168 \text{ N } (3\text{sf})$ **OR** $v^2 = u^2 + 2a_{ave}s$ $0 = 7.0^2 + 2a_{ave}(7.6)$ average accel., $a_{ave} = -3.22 \text{ m s}^{-2}$ Average frictional force $= ma_{ave} = (52)(3.22)$ $= 168 \text{ N}$	**M1** **A1** **(M1)** **(A1)**
	(b)	**(i)**	When the carousel rotates, the chair and its occupant will travel in a straight-line if not for the cable attached to it. <u>A horizontal (centripetal) force is required</u> in order to pull the man towards the centre. This is provided by the <u>horizontal components of the tension</u> on the cable holding the chair. Thus, the cable has to tilt to provide for the needed centripetal force.	**M1** **A1**
		(ii)	 All forces must be indicated and labelled in words (not in letters or symbols). <u>Tension</u> on cable and <u>gravitational force</u> (or <u>weight</u>) on person and seat. Deduct mark if FBD includes *centripetal* or *centrifugal* force, *normal* force or any irrelevant forces.	**B1**

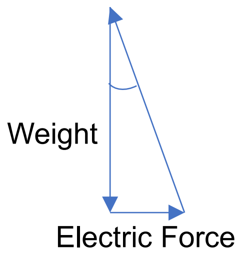
		(iii)		Along the y-direction: $T\cos\theta = mg$ (balanced) Along the x-direction: $T\sin\theta = mr\omega^2$ (unbalanced due to centripetal rotation) $r = 4.7 + 8.4\sin 35° = 9.518$ m $\tan\theta = \dfrac{mr\omega^2}{mg} = \dfrac{r\omega^2}{g}$ $\tan 35° = \dfrac{(9.518)\omega^2}{9.81}$ $\omega = 0.85$ rad s^{-1}	**C1** **C1** **A1**

2	**(a)**			The first law of thermodynamics states that the increase in internal energy of a system is the sum of the heat (thermal energy) supplied to the system and the work done on the system.	**B1**
	(b)	**(i)**	**1.**	$W_{on} = -P\Delta V$ $= -(2.79\times10^5)\left[(1125-950)\times10^{-6}\right]$ $= -48.825 = -48.8$ J (3sf) Max 1m for positive answers.	**C1** **A1**
			2.	$\Delta U = Q_{in} + W_{on}$ $W_{on} = 0$, since no volume change for Q $\rightarrow$ R $Q_{in} = \Delta U = \Delta\left(\dfrac{3}{2}pV\right)$ $= \dfrac{3}{2}\left[(2.10\times10^5)(1125\times10^{-6}) - (2.79\times10^5)(1125\times10^{-6})\right]$ $= -116.44$ $Q_{loss} = -Q_{in} = 116$ J (3sf) Max 2m for negative answers, but do not penalize if same type of mistake in **1.**	**C1** **C1** **A1**
		(ii)		Since there is no heat loss/gained, and there is (positive) work done on the gas through the compression (decrease in volume), the internal energy will increase. Hence, the temperature will increase.	**M1** **A1**

		(iii)	At point P: $$pV = nRT$$ $$(2.79\times10^5)(950\times10^{-6}) = n(8.31)(350)$$ $$n = 0.09113 = 0.091\text{ mol }(2\text{sf})$$ **OR** At point Q: $$pV = nRT$$ $$(2.79\times10^5)(1125\times10^{-6}) = n(8.31)(414)$$ $$n = 0.09124 = 0.091\text{ mol }(2\text{sf})$$ $Q = nC(\Delta T)$ $= 0.091(20.8)(414-350)$ $= 121\text{ J }(3\text{sf})$ **OR** $$\Delta U = \frac{3}{2}nR\Delta T = W_{on} + Q_{in}$$ $$\frac{3}{2}(0.091)(8.31)(414-350) = -48.8 + Q_{in}$$ $$Q_{in} = 121\text{ J }(3\text{sf})$$	**B1** **(B1)** **C1** **A1** **(C1)** **(A1)**

3	**(a)**		The graph shows a linear line passing through the origin. This shows that acceleration is proportional to displacement. The graph shows a negative gradient. This means that acceleration and displacement is always in opposite direction.	**B1** **B1**
	(b)		$a = -\omega^2 x$ Hence, using one of the data point (−0.04,0.32), $0.32 = -\omega^2(-0.04)$ $\omega^2 = 8.0$ $\omega = \sqrt{\frac{k}{L}} \Rightarrow k = \omega^2 L$ $k = (8.0)(1.24)$ $= 9.92\text{ m s}^{-2}$	**C1** **C1** **A1**
	(c)		Increasing the length decreases the angular frequency. Since total energy of oscillation = $\frac{1}{2}m\omega^2 x_0{}^2$, and total energy does not change, the amplitude is inversely proportional to angular frequency². increasing the length will increase the amplitude of oscillation.	**M1** **A1**

4	**(a)**		Coulomb's law states that the magnitude of the electric force between two point charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of their separation.	**B1**

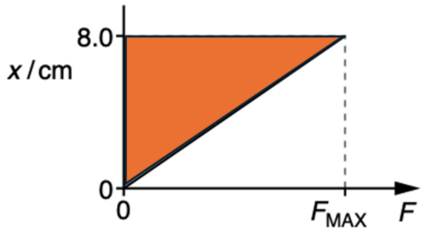
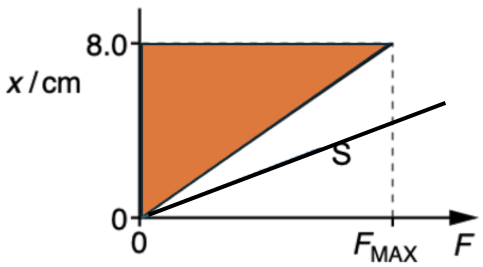
	(b)	(i)	Electric force, $F_E = \dfrac{96\times10^{-9}\times Q_Y}{4\times\pi\times8.85\times10^{-12}\times0.080^2}$ angle to the vertical, $\theta=\sin^{-1}\left(\dfrac{0.080}{1.2}\right)(=3.823°)$ $F_E = mg\tan\theta$ $=(0.013)(9.81)\tan(3.823^o)$ OR $=(0.013)(9.81)\left[\dfrac{0.080}{\sqrt{1.2^2-0.080^2}}\right]$  $\dfrac{96\times10^{-9}\times Q_Y}{4\times\pi\times8.85\times10^{-12}\times0.080^2}=(0.013)(9.81)\tan(3.823^o)$ $Q_Y = 63$ nC (shown)	M1 M1 A0
		(ii)	$\phi_{net}=\dfrac{96\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.040}+\dfrac{63\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.040}$ $=21580+14162$ $=3.57\times10^4$ V	C1 A1
	(c)	(i)	$E=\dfrac{V}{d}=\dfrac{250}{0.018}\left(=1.389\times10^4\text{ V m}^{-1}\right)$ $a=\dfrac{F}{m}=\dfrac{qE}{m}=\dfrac{\left(1.6\times10^{-19}\right)\left(1.389\times10^4\right)}{\left(9.11\times10^{-31}\right)}$ $=2.4\times10^{15}\text{ m s}^{-2}\,(2\text{sf})$	M1 M1 A0
		(ii)	time taken to travel through the parallel plates = length/ speed $=\dfrac{20\text{ cm}}{2.0\times10^7}\left(=1.0\times10^{-8}\text{ s}\right)$ final vertical speed $=u_y+a_yt=0+\dfrac{F}{m}t$ $=\left(2.4\times10^{15}\right)\left(1.0\times10^{-8}\right)$ $\left(=2.4\times10^7\text{ m s}^{-1}\right)$ speed $=\sqrt{\left(2.0\times10^7\right)^2+\left(2.4\times10^7\right)^2}$ $=3.1\times10^7\text{ m s}^{-1}$	C1 C1 A1
		(iii)	The <u>polarity of the charge is different</u>, so the force will be in the opposite direction to that of the electron. Hence, the proton will be <u>deflected down</u> instead of up. The <u>mass of the proton is heavier</u> than that of the electron, so the acceleration is lower. Hence, the <u>deflection will be less</u> than that of the electron.	B1 B1

5	(a)	(i)	Resistance is <u>infinite</u> / <u>very high</u>	B1
		(ii)	<u>Resistance decreases as V increases</u> (Ratio of V/I increases)	B1
	(b)	(i)	$R = \rho L/A$ $\rho = (18\times\pi(0.15\times10^{-3})^2/0.94$ $= 1.4\times10^{-6}\ \Omega$ m	B1

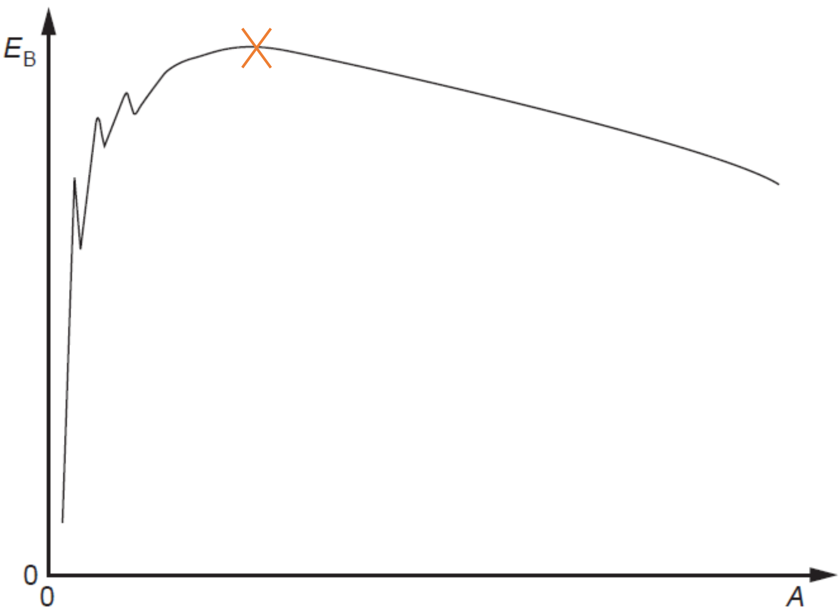
		(ii)	p.d. across wire = $\frac{18}{18+2.0}(6.2) = 5.58$ V Since S is at the mid-point, pd across half the length of the wire = ½ (5.58) Voltmeter reading = 2.8 V	**C1** **A1**
		(iii)	Current in the battery: increase Voltmeter reading: decrease	**B1** **B1**
	(c)	**(i)**	$I = Anvq$ $q = 0.93/[(\pi(0.15 \times 10^{-3})^2) \times (9.0 \times 10^{28}) \times (1.3 \times 10^{-3})]$ $= 1.1 \times 10^{-19}$ C	 **A1**
		(ii)	The charge carriers in a metal wire are the electrons which has a charge of 1.6×10^{-19} C. <u>Charge q is less than 1.6×10^{-19} C the elementary charge</u>. So the value must be wrong	**B1**

6	**(a)**	**(i)**	Since the <u>velocity is always right angle to the magnetic field</u>, by Fleming's left hand rule, <u>the magnetic force always be right angle to its velocity.</u> The force <u>only changes the direction of the motion and not its speed.</u> This results in circular motion.	**B1** **B1**
		(ii)	Out of page	**B1**
		(iii)	The magnetic force provides the centripetal force $Bqv = \frac{mv^2}{r}$ $B = \frac{mv}{qr} = \frac{(20 \times 1.66 \times 10^{-27})(5.6 \times 10^5)}{(1.6 \times 10^{-19})(0.051)}$ $B = 2.3$ T	**B1** **C1** **A1**
	(b)	**(i)**	Upwards	**B1**
		(ii)	$qE = Bqv$ $E = Bv = (2.3)(5.6 \times 10^5)$ $= 1.3 \times 10^6$ V m^{-1}	 **C1** **A1**

7	**(a)**	**(i)**	$m_x u_x + m_Y u_Y = m_x v_x + m_Y v_Y$ $50(4.5) + M(-2.8) = 50(-1.8) + M(1.4)$ $M = 75$ g	 **M1** **A1**
		(ii)	<u>Total kinetic energy of the system before and after collision is the same</u>.	**B1**

		(iii)	Using KE: $\frac{1}{2}m_x u_x^{\ 2}+\frac{1}{2}m_x u_x^{\ 2}=\frac{1}{2}\left[0.050(4.5)^2+0.075(-2.8)^2\right]=0.80$ J $\frac{1}{2}m_x v_x^{\ 2}+\frac{1}{2}m_x v_x^{\ 2}=\frac{1}{2}\left[0.050(-1.8)^2+0.075(1.4)^2\right]=0.15$ J Since final KE < initial KE, inelastic collision **OR** Using relative speed $u_X-u_Y=4.5-(-2.8)=7.3$ m s^{-1} $v_Y-v_X=1.4-(-1.8)=3.2$ m s^{-1} Since relative speeds are not the same, inelastic collision	**M0** **M1** **A1** **(M0)** **(M1)** **(A1)**
		(iv)	Since total initial momentum is not zero, having both objects concurrently at rest means that instantaneous total momentum is zero. Hence, not possible due to conservation of linear momentum	**B1** **B1**
	(b)	**(i)**		**B1**
		(ii)	$\Delta KE=\Delta EPE$ $\frac{1}{2}mv^2=\frac{1}{2}F_{MAX}x$ $\frac{1}{2}(0.50)(0.25)^2=\frac{1}{2}F_{MAX}(0.080)$ $F_{MAX}=0.39$ N	**M1** **A1**
		(iii)	 B1: Line should be less steep B1: Line should extend further rightward than original	**B1** **B1**
	(c)	**(i)**	Net increase in weight when ballasts are completely filled with sea water from 25% full: $\Delta W=0.75(2\times 50)(1030)(9.81)$ $\Delta W=757822.5=7.6\times 10^5$ N	**M1** **A0**

		(ii)	New mass of submarine $m = 2.2 \times 10^6 + \dfrac{757822.5}{9.81} = 2277250$ kg $a = \dfrac{\Delta W}{m} = \dfrac{757822.5}{2277250}$ $a = 0.33$ m s^{-2}	**M1** **A1**
		(iii)	When the submarine descends at an angle, the surface area that is considered for drag is smaller. Hence the downward component of velocity of the submarine is higher when it is descending at an angle.	**M1** **A1**
		(iv)	The water molecules gain an upward momentum after impact with the angled dive plane. Hence by N2L, an upward force is exerted on the water molecules due to the dive plane. By N3L, a downward force is exerted on the dive plane by the water molecules, resulting in the submarine being pushed downwards	**M1** **A1** **B1**

8	**(a)**		Binding energy = [Total mass of the unbounded nucleons - mass of Iron nucleus]c^2 $\text{BE} = \left[(26 \times 1.00728 + 30 \times 1.00866) - 55.92132\right] uc^2$ $= (0.52776)(1.66 \times 10^{-27})(3 \times 10^8)^2$ $= 7.88 \times 10^{-11}$ J $\text{BE per nucleon} = \dfrac{7.88 \times 10^{-11}}{56} = 1.4 \times 10^{-12}\text{J} = \dfrac{1.4 \times 10^{-12}}{1.6 \times 10^{-19}}$ eV $= 8.8$ MeV	**B1** **M1** **M1** **A0**
	(b)	**(i)**	Near to the highest point on the graph  	**B1**
		(ii)1.	Neutron	**B1**
		(ii)2.	Since the nucleus are of nucleon numbers less that Fe-56, base on the graph, the binding energy per nucleon increases with higher nucleon number. The energy used to break the hydrogen isotopes are thus less than the energy released use to form helium nucleus	**B1** **B1**

		(iii)	Energy released = BE of products – BE of reactants = (mass defect of products - mass defect of reactants)c^2 = (0.030377 – 0.002388 – 0.009105)uc^2 = 2.8 x 10^{-12} J	 **C1** **A1**
	(c)		If there is no other particle, beta particle would always have the same energy. By conservation of energy and momentum, there must be another particle to share energy/momentum	**B1** **M1** **A1**
	(d)	**(i)**	Comparing the interval between N = 12 x 10^{12} and N = 12 x 10^{12}, Δt = 0.52 s Therefore, half-life = 0.52 s $\lambda = \frac{\ln 2}{t_{½}} = \frac{\ln 2}{0.52}$ $= 1.3\ \text{s}^{-1}$	 **M1** **A1**
		(ii)	Check that number of thorium + protactium is always N (marker to check they intersect at 12, and two more values to add to 24 x 10^{12}) Increasing graph with decreasing gradient	**B1** **B1**
		(iii)	$\text{initial activity} = (\lambda)(\text{initial number of nucleons})$ $= (1.3)(24 \times 10^{12})(= 3.1 \times 10^{13})$ $\text{Activity at 1.5 s} = 3.1 \times 10^{13} e^{-(1.3)(1.5)}$ $= 4.4 \times 10^{12}\ \text{Bq}$	 **C1** **C1** **A1**
		(iv)	The Geiger counter was only used to count the radioactive particle that enters the GM tube. Since the radioactive particle are released in random direction, not all the radioactive particle us captured by the counter.	 **B1**