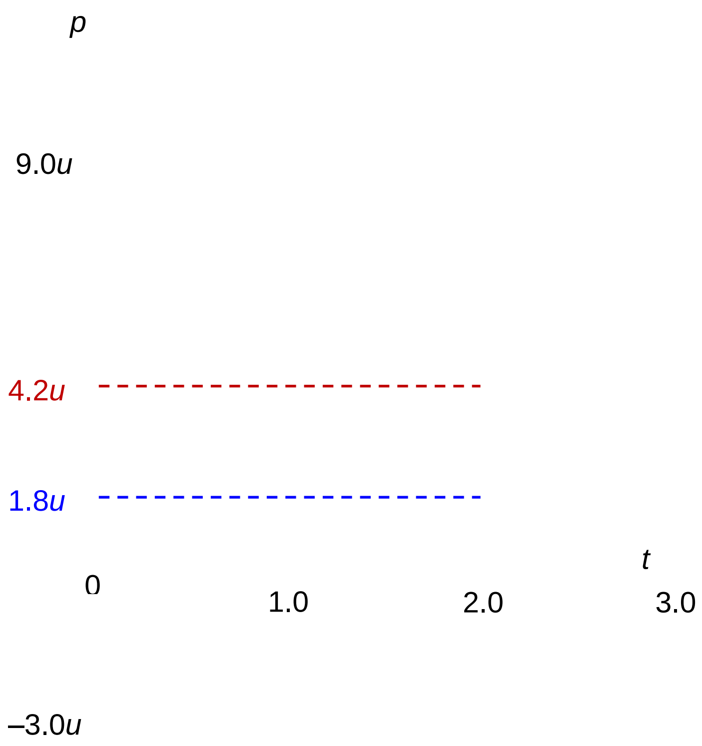
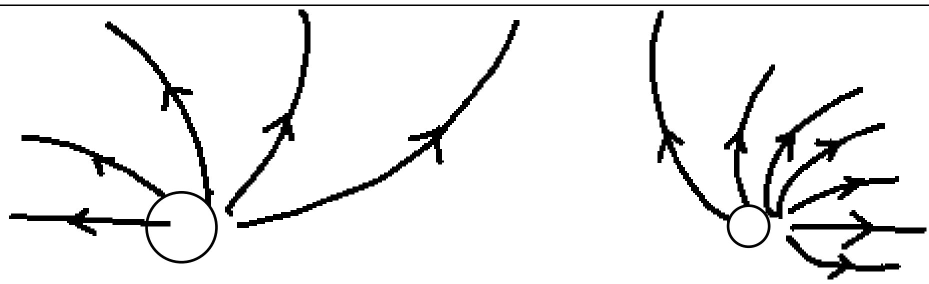
2023 MI PU3 H2 Physics Prelim Paper 3 Suggested Solution

1a(i)	No external forces act on the system of two objects. OR The two objects form a closed system.	B1
(ii)	Straight line from (1.0, -3.0u) to (2.0, 4.2u) Horizontal line at p = 4.2u from t = 2.0 to 3.0 s 	B1 B1
(iii)	Since the <u>total momentum before the collision is 6.0*u*</u>, the <u>total momentum</u> of the system <u>remains constant at</u> <u>6.0*u* at all times</u>. So final p of object B = 6.0u – 1.8u =4.2u OR Since <u>p of object A decrease by 7.2u</u> after the collision, <u>p of particle B will increase by 7.2*mu*.</u> So final p of particle B = -3.0u + 7.2u = 4.2u	B1
1b	v_A = 1.8u / 9.0 = 0.2u v_B = 4.2u / 1.0 = 4.2u	

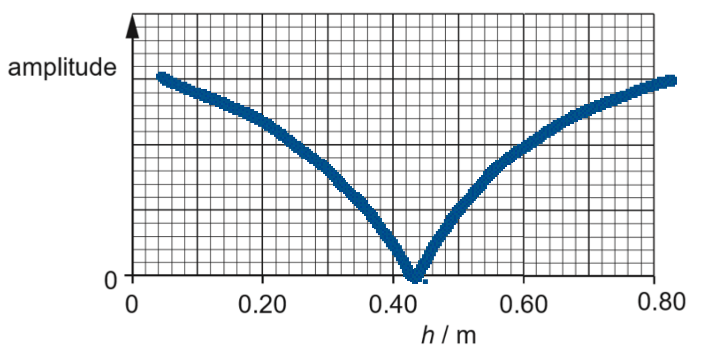
	relative speed of approach= $u_A - u_B = u - (-3u) = 4u$ relative speed of separation= $v_B - v_A = 4.2u - 0.2u = 4u$ Since the <u>relative speed of approach and the relative speed of separation are equal</u>, the collision is <u>elastic</u>. OR kinetic energy, $E_k = \frac{1}{2}mv^2 = \frac{1}{2}\frac{(mv)^2}{m} = \frac{p^2}{2m}$ before collision: $E_{k,before} = \frac{{p_{A,before}}^2}{2m_A} + \frac{{p_{B,before}}^2}{2m_B} = \frac{(9.0u)^2}{2(9.0)} + \frac{(-3.0u)^2}{2(1.0)} = 9.0u^2$ after collision: $$E_{k,after} = \frac{{p_{A,after}}^2}{2m_A} + \frac{{p_{B,after}}^2}{2m_B} = \frac{(1.8u)^2}{2(9.0)} + \frac{(4.2u)^2}{2(1.0)} = 9.0u^2$$ Since the <u>kinetic energy of the system before and after the collision remains the same</u>, the collision is <u>elastic</u>.	M1 M1 A1 (M1) (M1) (A1)
1c(i)	$$F = \frac{\Delta p}{\Delta t}$$ $$= \frac{(1.8u - 9.0u)}{(2.0 - 1.0)}$$ = (-) 7.2u (accept + or – answer) Therefore, magnitude of F is 7.2u	M1 A0
(ii)	By Newton's second law, gradient of p vs t graph represents resultant force. During collision, <u>gradient</u> of graph of object A and object B have <u>equal magnitude</u>, showing that <u>forces</u> acting on A and B have <u>equal magnitude</u>. The gradients have <u>opposite signs</u> indicate that the two forces act <u>in opposite directions.</u> Hence the graphs are consistent with Newton's third law	 B1 B1
	Total:	10

2a	Total volume of molecules is negligible compared with volume occupied by the gas	B1
2b	$pV = NkT$ $2.10 \times 10^5 \times 950 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times (280)$ $N = 5.16 \times 10^{22}$ volume of one molecule = $(4 / 3)\square r^3$ (= 1.41×10^{-29} m^3) volume of all molecules = $5.16 \times 10^{22} \times 1.41 \times 10^{-29}$ = 7.3×10^{-7} m^3 = 7×10^{-7} m^3 (**1 s.f**.; as this is an estimation question the uncertainty of final answer cannot be more precise than that of the given data.) **OR** volume of one molecule = d^3 (= 2.7×10^{-29} m^3) volume of all molecules = $2.7 \times 10^{-29} \times 5.16 \times 10^{22}$ = 7×10^{-7} m^3 (**1 s.f**.; as this is an estimation question the uncertainty of final answer cannot be more precise than that of the given data.)	 C1 C1 A1 (C1) (C1) (A1)
2c	Since volume of all atoms (1×10^{-6} m^3) is *3 orders of magnitude less* than volume occupied by the gas (950×10^{-6} m^3 H 1×10^{-3} m^3) OR 0.1% of volume occupied by the gas so assumption in (a) is justified.	B1
2d(i)	Internal energy depends on temperature. Since final temperature equal initial temperature so **no change in total internal energy**	B1 B1
2d(ii)	For P → Q: work done on gas = **0 J** and increase in internal energy, ⊗U = Q + W = +97.0 + 0 = **97.0 J** For Q → R: increase in internal energy, ⊗U = 0 -42.5 = **–42.5 J** For R→P: work done on gas, $W = p\,\Delta V = 2.10 \times 10^5 \times (1125 - 950) \times 10^{-6}$ = **36.8 J** since total change in internal energy is zero, $+97 + (-42.5) + \Delta U_{RP} = 0$ increase in internal energy, ΔU_{RP} = **–54.5 J** thermal energy supplied, $Q = \Delta U - W = -54.5 - 36.8$ = **–91.3 J**	 A1 A1 A1 A1 A1
	Total:	12

3a	upthrust and weight	B1
3b	**upthrust greater than weight** so resultant force is **upwards**	B1
3c(i)	*A*, *g* and *ρ* all constant so *F* is proportional to *x* minus sign means *F* and *x* are in opposite directions	B1 B1
3c(ii)	$$a = \frac{F}{m} = (-)\frac{Ag}{m}x$$ compare with SHM defining equation $a = -\omega^2 x$ $$\omega^2 = \frac{A\rho g}{m}$$ $$\omega = \sqrt{\frac{Ag}{m}}$$	M1 M1 A0
3d(i)	Damping due to viscous forces	B1
3d(ii)	$-\omega^2 = gradient = \frac{2\cdot30}{0.020} = 115$ $$(2\pi f)^2 = 115$$ f = 1.71 = 1.7 Hz	C1 A1
3d(iii)	$$E = \frac{1}{2}kx^2 = \frac{1}{2}mw^2x$$ $$initial\ E = \frac{1}{2}(O.57)(115)(0.020)^2 = 0.01311\,J$$ $final\ E = \frac{1}{2}(0.57)(115)(0.016)^2$ = 0.0083904 J $$\Delta E = Initial\ E - final\ E$$ $$= 4.7\ x\ 10^{-3}J$$ OR accept if students use area under graph to final initial and final E read off first point (-0.02,2.3) gives initial E = 0.01311 J accept either: read off second point as (0.016, -1.8) gives final E = 0.008208, hence $\Delta E = 4.9\ x\ 10^{-3}J$ read off second point as (0.016, -1.84) gives final E = 0.0083904 hence $\Delta E = 4.9\ x\ 10^{-3}J$	C1 C1 A1
	Total:	12

4a	Zero electric field strengths in sphere A(between $x = 0$ and $x = 1.4$ cm) and in sphere B (between $x = 11.4$ and $x = 12.0$ cm)	B1
4b	Since the field strength is zero at a point between the spheres OR the electric fields are in opposite directions, the charges on the spheres are of the same sign.	M1 A1
4c	At $x = 0.08$ m, the electric field strength due to sphere A cancels out the electric field strength due to sphere B. $E_A = E_B$ $\frac{Q_A}{4\pi\varepsilon_o\,(0.08)^2} = \frac{Q_B}{4\pi\varepsilon_o\,(0.04)^2}$ $\frac{Q_A}{Q_B} = \left(\frac{0.08}{0.04}\right)^2 = 4$ (Allow estimation from graph, 7.8 cm < x < 8.2 cm)	 B1 C1 A1
4d	 ● Correct field line direction (either all inwards or all outwards) and shape ● neutral point nearer to sphere B and any of the following: ● field lines more closely spaced for sphere B ● field lines perpendicularly from the spheres	 B1 B1 B1
4e	change in electric potential = area under graph between $x = 1.4$ cm and $x = 3.0$ cm Estimated area between $x = 1.4$ cm and $x = 3.0$ cm $= \frac{1}{2}(0.8 \times 10^{-2})(11.0 + 5.0)10^7 + \frac{1}{2}(0.8 \times 10^{-2})(5.0 + 2.5)10^7$ = 940 kV Or by counting squares under graph. Acceptable range for either method is between 850 kV and 1050 kV. Energy gained by proton = $(940 \times 10^3)(1.60 \times 10^{-19})$ $= 1.5 \times 10^{-13}$ J Accept $(1.4 \text{ to } 1.6) \times 10^{-13}$ J	 C1 C1 A1
	Total:	12

5a(i)	$\left(E = BE_{products} - BE_{reactantan\ t\ s}\right)$ E = (BE per nucleon of C) x 12 – 3 x (BE per nuceon of He x 4) $E = [12 \times (7.680) - 3 \times (4 \times 7.074)]$ =7.272 MeV	C1 A1
5a(ii)	$P = \dfrac{E_{total}}{t}$ $= \dfrac{\text{number of reactions} \times E_{\text{each reaction}}}{t}$ $\dfrac{\text{number of reactions}}{t} = \dfrac{P}{E_{\text{each reaction}}} = \dfrac{2.75 \times 10^{26}}{7.272 \times 10^{6}\left(1.6 \times 10^{-19}\right)}$ $\left(= 2.3635 \times 10^{38}\ \text{s}^{-1}\right)$ $\dfrac{n}{t} = \dfrac{number\ of\ reactions}{t} \times 3 = (2.3635 \times 10^{38})(3)$ $\dfrac{n}{t} = 7.09 \times 10^{38}\ helium\ nuclei\ per\ second$	C1 C1 A1
5b(i)	*714X* *−10e*	B1 B1
5b(ii)1.	Observation 1: electrons/®-particles (emitted from the nucleus) have a (continuous) range of/ different (kinetic) energies OR Observation 2: electrons/®-particles and daughter nuclei X are not in opposite directions	B1
5b(iii)2.	Explanation for observation 1: Since the energy released in each decay is **same/fixed** by the principle of conservation of energy there must be **neutrinos** (emitted) to **take varying amounts of the** (same total) **energy** (released in the decay) so that electrons can take different/range of kinetic energy OR Explanation for observation 1: By conservation of momentum there must be **neutrinos** (emitted) such that the sum of momentum of neutrino and electron is in the opposite direction of the daughter nuclei X direction of neutrinos varies so electrons can be emitted in varying directions	 B1 B1, (B1) (B1)
5c(i)	tangent drawn and gradient calculation attempted activity = 1.3×10^{6} Bq (accept answer within $\pm 0.2 \times 10^{6}$ Bq)	B1 A1
5c(ii)	A = λN $\lambda = (1.3 \times 10^{6})/(3.05 \times 10^{10})$ $= 4.3 \times 10^{-5}\ \text{s}^{-1}$ ($\approx 4 \times 10^{-5}$ s –1)	B1 M1 A0
	Total:	14

6a	distance moved by wavefront/energy during one cycle/oscillation/period (of source)	B1
6b	$T = 2.0 \times 2.5$ (= 5.0 ms) $f = 1 / (5.0 \times 10^{-3})$ = 200 Hz	 A1
6c(i)	(incident) **wave reflects at end/top of tube** (incident) **wave and reflected wave interfere/superpose** to produce stationary wave	B1 B1
6c(ii)	line has maximum value of amplitude at h = 0 and h = 0.80 m only line has minimum/zero value of amplitude at h = 0.40 m only 	B1 B1
6c(iii)1.	vertical/along length of tube/along axis of tube	B1
6c(iii)2.	phase difference = 0°	A1
6c(iv)	⌊ = 2 X 0.80 = 1.6 m	A1
6d(i)	path difference = $8.0 + (20.8^2 - 8.0^2)^{0.5} - 20.8$ = 6.4 m	M1 A0
6d(ii)	• **<u>path difference</u> = 4λ** waves (meet at C) in phase • **constructive interference** (of waves) occurs	B1 B1
6d(iii)	$v = 200 \times 1.6$ = 320 m s^{-1} Δt = 6.4 / 320 **or** 27.2 / 320 – 20.8 / 320 = 0.020 s	 C1 A1
6d(iv)	3λ = 6.4 λ = 2.1 m	C1 A1
6e(i)	Use Malus' law, Intensity $I = I_o \cos^2$ (Intensity $I = I_o \cos^2$ ($= I_o \cos^2 45°$ $= I_o/2$	 C1 A1

	And orientation to the vertical is 45°	
6e(ii)	Intensity $I = (I_o \cos^2 45°) \cos^2 45°$ $= I_o/4$ and orientation to the vertical is 0° (i.e. emergent beam is polarised vertically)	C1 A1
	Total:	20

7a(i)	Faraday's Law of Electromagnetic Induction states that the induced e.m.f is directly proportional to the rate of change of magnetic flux linkage.	B1
7a(ii)	A (primary) **coil** is installed **in the charging plate** and a another (secondary) **coil in the device**. A **changing magnetic flux** is produced in the (primary) **coil of the charging plate**, due to the alternating current from the power source. By Faraday's law, an **emf** will be **induced** in the (secondary) **coil of the device** which will charge the device.	B1 B1 B1
7a(iii)	Advantage: (any valid suggestion) ● No connecting wires required between device and charging plate, so less risk of electrical shock. ● Can fully enclose the charging parts to make it water-proof. Disadvantage: (any valid suggestion) ● Coils of wires are required to be installed inside the device, hence more bulky/costly. ● Less efficient than wired connection due to resistive heating (Lenz's law). ● Longer charging time. ● Device will need to stay with the charging plate and is not mobile when charging.	B1 B1
7b(i)	$2\pi f = 377 f = \frac{377}{2\pi} = 60.0\ Hz$	C1 A1
7b(ii)	$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{340}{\sqrt{2}}$ $= 240\ V$	C1 A1
7b(iii)	It means that this alternating supply voltage will provide the same average/mean power (or rate of heat dissipation) as an equivalent steady direct voltage of 240 V.	B1
7c(i)	$\varepsilon = BLv = (0.54)(0.100)(2.3) = 0.1242 = 0.124\ V$	C1 A1
7c(ii)	end C	B1
7c(iii)	$I = \frac{\varepsilon}{R} = \frac{0.1242}{0.83}$ $= 0.1496 = 0.150\ A$	C1 A1
7c(iv)	By Fleming's LHR, since current flows from A to B and magnetic field is into the plane, so force on rod AB is **towards right**.	M1 A1
7c(v)	$F = BIL = (0.54)(0.1496)(0.100)$ $= 8.08 \times 10^{-3}\ N$ $a = \frac{F}{m} = \frac{8.08 \times 10^{-3}}{0.034}$ $= 0.238\ m\ s^{-2}\ \ [A1]$	C1 A1
	Total:	20