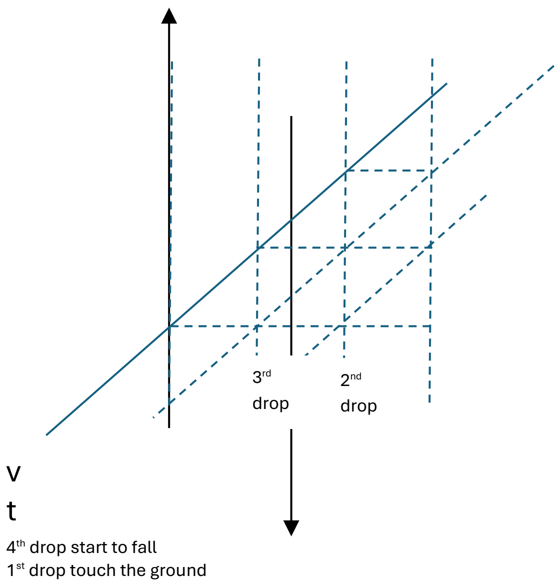
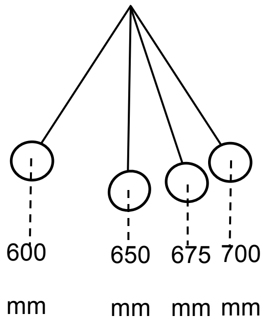
NJC Preliminary Examination 2024
H2 Physics Paper 1

Solutions

1	2	3	4	5	6	7	8	9	10
C	C	A	B	A	A	C	A	B	B
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
B	A	B	B	B	D	C	B	C	D
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
C	D	A	A	C	A	B	C	B	D

1	C	1 per second, 3600 per hour
2	C	by definition
3	A	Slope has constant gradient. $v^2 = u^2 + 2as$. So KE is proportional to the displacement with a being negative.
4	B	Let time interval between each drop be t. First drop took 3t to reach the ground and travelled 9 m $9 = 0\,(4t) + \frac{1}{2}(g)(3t)^2$ $t^2 = \frac{2}{g}$ distance travelled by 2nd drop = $0(2t) + \frac{1}{2} g\,(t)^2$ distance travelled by 3rd drop = $0\,(3t) + \frac{1}{2} g\,(2t)^2$ distance between 2nd and 3rd drop = $\frac{1}{2} g\,(2t)^2 - \frac{1}{2} g\,(t)^2 = 3.0$ m alternative solution:  distance between 1st drop and 4th drop = 9 triangles = 9m distance between 2nd and 3rd drop = 3 triangles = 3m
5	A	F = 70 = (20+6) a a = 2.692 ms^{-2} f on B = 6 a = 16.15 N (to right) N3L, f on A = f on B = 16.15 N = 16 N (2sf) (to left)
6	A	Taking moments. A has the greatest moments.
7	C	Kinetic energy is conserved only for elastic collision, momentum is conserved for both elastic and inelastic

8	A	GPE = KE 0.3 (9.81) (2) = 5.886 = ½ (0.3) v^2 v = 6.2641 m s^{-1} $P_i = P_f$ 0.3 (6.2641) = (0.3 + 0.5) V V = 2.3491 m s^{-1} KE after collision = ½ (0.8) 2.3491^2 = 2.20725 J therefore EPE = 5.886 – 2.20725 = ½ k $(0.20)^2$ k = 184 N m^{-1} (3 s.f.)
9	B	At B, resultant force towards centre of dome $F_{net} = mg \cos 48.2^o$ Centripetal acceleration = F_{net} / m = $g \cos 48.2^o = 6.54$ m s^{-2}
10	B	Geostationary orbit is always at the same radius, have the same period and mass does not affect the orbit
11	B	Uniform g field has the same g field strength at all points
12	A	Mean speed $= \frac{(2+10+11)u}{3} = 7.67u$ Mean square speed $= \frac{(4+100+121)u^2}{3} = 75u^2$ Root mean square speed $= u\sqrt{75} = 8.66u$
13	B	$pV = nRT = \frac{m}{M}RT$ At constant pressure and volume, $mT =$ constant. $m_2T_2 = m_1T_1$ ® $m_2 = \frac{m_1T_1}{T_2} = \frac{(273+10)}{(273+30)} \times 15 = 14$ kg
14	B	Q = Pt = mcΔ(P = mc(Δ(/t) P and m is constant, Δ(/t is bigger for liquid than solid, therefore specific heat capacity c is smaller for liquid than solid. (A is wrong) Q = mL 2000 x 3 = 1 x L □ L = 6000 J kg^{-1} (B is correct) The substance melts after an increase in temperature of 3K from room temperature. The melting temperature is not 3K. (C is wrong) Unless the graph becomes horizontal again, we are unable to determine when the substance starts to become gaseous. And only after it stops being horizontal again will it be completely gaseous. (D is wrong)

15	B	 Taking the initial position at 650 mm mark, $x = x_0 \; sin \; sin \; \omega \; t = x_0 \; sin \; sin \; \left[\left(\frac{2\pi}{T}\right)t\right] \; 25 = 50 \; sin \; sin \; \left[\left(\frac{2\pi}{2}\right)t\right] \; t = 0.167 \; s$ $x = x_0 \; sin \; sin \; \omega \; t = x_0 \; sin \; sin \; \left[\left(\frac{2\pi}{T}\right)t\right] \; 10 = 50 \; sin \; sin \; \left[\left(\frac{2\pi}{2}\right)t\right] \; t = 0.064 \; s$ t_{Total} = 0.167 + 0.064 = 0.231 = 0.23 s
16	D	$y = A \; cos \; cos \; \theta$ $y_P = \pm A = A \; cos \; cos \; \theta_P \; \Rightarrow \theta_P = 0°, 180°$ $y_Q = \pm \frac{1}{3} A = A \; cos \; cos \; \theta_Q \; \Rightarrow \theta_Q = 70.5°, 109°$
17	C	Intensity proportional to (amplitude)^2 × (frequency)^2. $\frac{I'}{I} = \left(\frac{1.2}{2.4}\right)^2 \left(\frac{15}{5}\right)^2 = \frac{9}{4}$
18	B	$d \sin\theta = n\lambda$ $4\lambda \sin\theta = 2\lambda$ $\sin\theta_1 = 0.5, \longrightarrow \theta_1 = 30$ $\sin\theta_2 = \frac{3\lambda}{4\lambda} \longrightarrow \theta_2 = 48.59^0$ $48.59^0 - 30^0 = 18.59^0 \approx 18.6^0$

19	C	Option A: Depending on the charge of the object, the force could either be left (positive charge) or right (negative charge). Option B: The magnitude of the field strength can be found using E = – dV/dr. The gradient at P is larger than Q, so the field strength is larger at P Option C: The potential at P is lower than R, and thus ΔV is a negative number. The work done is W = q ΔV and this is a positive number since q is also negative. So, the work done is positive Option D: The potential energy is given by U = qV, and so, since V is more negative at P than at R, the potential energy is lower at P than at R.
20	D	Using F = ma, thus eE = m a a = e(V/d) / m_e = 5.3 X 10^{17} m s^{-2}
21	C	There is no difference between the connections in diagram 1 and diagram 2. Since the lamps are of the same resistance, putting a wire across the points parallel to the lamps P and Q does nothing to change the circuit itself
22	D	Total energy provided by battery is 60J Emf is W/Q = 60/20 = 3.00 V Pd across r = 10/20 = 0.50 V Pd across R = 50/20 = 2.50 V
23	A	The forces acting on XY and ZW have the same magnitude in opposite directions. These two forces form a couple with a torque as follow: $\tau = NBIL \times d = (20)(0.80)(I)(0.17) \times (0.11) = 1.35$ I = 4.5 A
24	A	Negative charges gain KE as it loses EPE from Source S to the hollow metal container. qV = ½ mv^2 2V (q/m) = v^2 --- (1) Inside the hollow metal container, in order for the ions to pass through un-deviated, $F_B = F_E$ Bqv = qE = q(V/d) Bv = (V/d) v = (V/Bd) --- (2) Sub (2) in (1) $(V/Bd)^2$ = 2V (q/m) q/m = V / (2 B^2 d^2)

25	C	Emf of a rotating disc of radius L $= \frac{\text{Change in flux}}{\text{Time}}$ $= \frac{B.\pi L^2}{T}$ $= \frac{B.\pi L^2}{\frac{2\pi}{\omega}}$ $= \frac{1}{2} BL^2\omega$ $\lvert e \rvert = \frac{1}{2} BL^2\ \omega.$ Emf between R and S = ½ $BL^2\ \omega$ - ½ $B(L/2)^2\ \omega$ = ¾ (1/2 $BL^2\ \omega$) According to the question E = ½ $BL^2\ \omega$, therefore, emf between R and S is ¾ E
26	A	Since inner loop experiences decreasing flux linkage, current in the inner wire will flow in the same direction as that in the outer wire to oppose this deceasing flux linkage (Lenz's law). Since the rate of decrease of current with time is constant, the rate of decrease of B and hence flux linkage is constant, hence e.m.f. induced in inner loop is constant and the current in the inner loop is constant.
27	B	Clockwise: current pass through 200 ∧ only. anticlockwise: current pass through both resistors.
28	C	Photocurrent is proportional to intensity. Intensity is proportional to (amplitude)^2. $\frac{amplitude\ of\ wave\ P}{amplitude\ of\ wave\ Q} = \sqrt{\frac{intensity\ of\ wave\ P}{intensity\ of\ wave\ Q}} = \sqrt{\frac{photocurrent\ of\ wave\ P}{photocurrent\ \ of\ wave\ Q}}$ $= \sqrt{\frac{4}{1}} = 2$
29	B	Energy of red wavelength photon $= \frac{hc}{\lambda} \approx \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{600 \times 10^{-9}} \times \frac{1}{1.6 \times 10^{-19}} = 2.1\ eV$ Only option B's energy difference is the closest to red wavelength
30	D	Nucleon number = 232 – 4 + 0 + 0 + 0 – 4 = 224 Proton number = 90 – 2 + 1 + 1 + 0 – 2 = 88

NJC Preliminary Examination 2024
H2 Physics Paper 2

Solutions and Mark Scheme

1 **(a)** Use $v_y = u_y + a_y t$
At max height, $v_y = 0$
0 = 30 sin 60° – (9.81) t M1

t = 2.6 s A0

(b) initial velocity = 26 m s^{-1}, final velocity = –26 m s^{-1} B1

straight line intersects *x*-axis at 2.6 s and ends at 5.2 s (or 5.3 s) B1

(c) **(i)** horizontal line at u_x = 15 m s^{-1} from t = 0 to 5.2 s (or 5.3 s) B1

(ii) downward sloping curve from 15 m s^{-1} and its gradient decreases numerically B1

ending before t = 5.20 s B1

(d) Calculate displacements of first and second object to be 34.4 m and 5.84 m respectively using 2.6 s (or 34.5 m and 5.31 m using 2.65 s) C1

Displacement between objects = 29 m A1

2 **(a)** Force is the <u>rate of change of momentum</u> B1

(b) **(i)** Resultant force = change of momentum / time taken = [0.140 x (5.5 – (– 4.0))]/0.04 M1

= 33 N A1

(ii) resultant force on ball = Δp/Δt = 33.25 N

Taking forces on the ball, (N is force on ball by bar)

33.25 = N – W M1

N = 33.25 + 0.14*9.81 = 34.62 N

By N3L, force on bar by ball is 35 N. A0

(c) **(i)** Taking pivot about support B,
clockwise moments = F_A x (45 – 25) C1

anti clockwise moments = (0.450 x 9.81) (25) + 35 (25 + 50) C1

Clockwise moments = anti clockwise moments
F_A = 136.768 N = 140 N (to 2 sf) A1

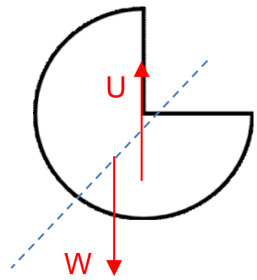
(ii) net force = 0
Upward force = downward force
F_B = 35 + 140 + 0.450 x 9.81 M1

= 180 N (to 2 sf) A1

3 **(a)** Pressure = ρgh = 900 x 9.81 x 6.0/100 M1

= 530 Pa A1

(b) weight and upthrust drawn in correct places (weight starts along the central blue dotted line and upthrust from centre of submerged part, ignore lengths) B1



the object turn anticlockwise (rotating ACW and CW with decreasing angle) until the weight and upthrust are on the same line of action (dotted line is vertical) B1

4 **(a)** The gravitational field strength at a point in a gravitational field is defined as the **gravitational force exerted per unit mass** acting on a small mass placed at that point. B1

(b) **(i)** point X is on the line and closer to Moon B1

(ii) Gravitational field strength at A = $\frac{G(5.97\times10^{24})}{(6.37\times10^{6})^2} - \frac{G(7.34\times10^{22})}{(3.84\times10^{8}-6.37\times10^{6})^2}$ = 9.81 m s^{-2}

Gravitational field strength at B = $\frac{G(7.34\times10^{22})}{(1.74\times10^{6})^2} - \frac{G(5.97\times10^{24})}{(3.84\times10^{8}-1.74\times10^{6})^2}$ = 1.61 m s^{-2}

Marks awarded as follow for both calculations:

- correct equations that include contributions by both Earth and Moon M1

- correct substitutions (e.g. unit conversion, etc) M1

- correct final values A1

(iii) Shape of graph, one positive one negative, cut x-axis closer to B. B1

5	**(a)**	**(i)**	Length of path 1 = 1.000 - 0.300 = 0.700 m Length of path 2 = 1.000 + 0.300 = 1.300 m Path difference = 1.300 – 0.700 = 0.600 m	B1
		(ii)	Phase difference $= \left(\frac{0.600}{1.000} \times 2\pi\right) \pm \pi$	M1
			$= 2.2\pi$ or 6.91 rad or 0.2π or 0.628 rad.	A1
		(iii)	Two segments / loops	M1
			One solid line + one dotted line	A1
		(iv)	Antiphase or π rad / 3.14 rad / 180° out of phase	A1
	(b)	**(i)**	For stationary waves to form, $L = 1.0 = n\left(\frac{\lambda}{2}\right)$ or $\lambda = \frac{2L}{n}$	M1
			From $v = f\lambda$	M1
			$f = \frac{v}{\lambda} = \left(\frac{n}{2L}\right)\sqrt{\frac{mg}{\mu}} = \left(\frac{n}{2}\right)\sqrt{\frac{mg}{\mu}}$ since $L = 1.000$	A0
		(ii)	$m = \frac{4f^2}{n^2}\left(\frac{\mu}{g}\right) = \frac{4(25)^2}{6^2}\left(\frac{7.0\times10^{-3}}{9.81}\right) = 0.050$ kg	A1
		(iii)	Next higher frequency has 8 segments	C1
			Frequency = 33 Hz	A1
6	**(a)**	**(i)**	From $V = IR$, $I = \frac{V}{R}$ hence $I \propto \frac{1}{R}$	C1
			Ratio = 1 : 0.5 : 0.2 or 10 : 5 : 2	A1
		(ii)	**1.** Q = Ne = $1.0 \times 10^{-3} \times 6.02 \times 10^{23} \times 1.6 \times 10^{-19}$ = 96.32 ≈ 96 C (shown)	A1
			2. Current through the resistor: $I = \frac{Q}{t} = \frac{96}{320} = 0.30$ A	M1
			Energy dissipated = I^2Rt = $(0.30)^2(4.0)(320)$ = 115.2 ≈ 115 J	M1
			OR	
			p.d. V = IR = 0.30 x 4.0 = 1.2 V	(M1)
			Energy = QV = 96 x 1.2 or Energy = $\frac{V^2}{R}t = \frac{1.2^2}{4.0} \times 320$	(M1)
			3. Let the current through R be I. Current through 4-ohm resistor = 3I Since resistors are in parallel: I x R = 3I x 4	M1
			R = 12 Ω	A1
	(b)	**(i)**	0.2 A	A1
		(ii)	1.0 V	A1

5 ohms A1

7 **(a)** 6, 6 A1

(b) **(i)** Decay constant is the probability of decay per unit time of a nucleus. B1

(ii) Half-life is the time taken for half the (number of radioactive nuclei/count rate/activity) present in any given sample of a given isotope to decay at any given time. B2

(c) Radioactive decay is a random process, in other words we don't know which nuclei will decay next; we only know the probability of decay.

After one half-life, it is not guaranteed that exactly half of the original atoms remain, but that this is just the most likely, and the average outcome.

Marks awarded as follow:
- meaning of random M1
- a reasonable discussion of what that means. A1

(d) **(i)** Original ratio = $\frac{C_{14,initial}}{C_{12,initial}} = \frac{1}{3.3\times10^{10}}$

Over the years, the ratio became $\frac{C_{14,final}}{C_{12,initial}} = \frac{1}{8.6\times10^{10}}$

$\frac{N}{N_o} = \frac{C_{14,final}}{C_{14,initial}} = \frac{C_{14,final}}{C_{12,initial}} \times \frac{C_{12,initial}}{C_{14,initial}} = \frac{1}{8.6\times10^{10}} \times \frac{3.3\times10^{10}}{1}$ C1

$= 0.384$ A0

Assumption: Ratio of C-12 to C-14 for a fresh sample of wood is constant/ C-12 remains the same B1

(ii) $N = N_0 e^{-\lambda t}$

$\lambda = \frac{ln2}{5700} = 1.2160 \times 10^{-4}$ y^{-1}

$0.384 = e^{-1.2160 \times 10^{-4}(t)}$ M1

$t = 2.49 \times 10^{11} s$ = 7870 years A1

8 **(a)** larger energy gap between conduction band and lower orbitals than standard silicon M1

resulting in a larger energy / higher frequency photons A1

(b) **(i)** wavelength = 595 nm C1

energy = $(6.63 \times 10^{-34})(3.00 \times 10^{8}) / (595 \times 10^{-9})$ (= 3.343×10^{-19} J) M1

energy = $3.343 \times 10^{-19} / 1.60 \times 10^{-19}$ = 2.09 eV or 2.1 eV A1

(ii) **1.** insufficient energy for electron to promote / excite to appropriate energy level B1

2. energy of the photons greater / wider gap between the conduction band and the lower orbitals than red LED B1
so higher energy per unit charge is required

(c) **(i)** point correctly plotted B1

(ii) even distribution of points on either side of the line along the full length B1

(iii) correct method to compute gradient i.e. Δy / Δx and coordinates are read accurate to half the smallest square M1

gradient calculated correctly (most line will give a gradient of about –1.7 to –1.8) A1

(d) **(i)** *either* obtain lg V_F from graph and V_F = 10^{value} (e.g. lg (520) = 2.716, lg V_F= 0.435)
or calculate *k* from *y*-intercept and substitute 520 nm into $V_F = k\,\langle\lambda\rangle^n$ M1

$V_F \approx$ 2.7 V (final answer depends on the line of best fit and rounding in the intermediate calculations) A1

(ii) p.d. across resistor = 4.5 – V_F from **(d)(i)**
resistance = p.d. / 20 mA M1

resistance ≈ 90 Ω A1

(e) **(i)** $v = c / n = 3.00 \times 10^{8} / 4.24$ M1

$v = 7.08 \times 10^{7}$ m s^{-1} A0

(ii) $n_1 \sin\sin\theta_1 = n_2 \sin\sin\theta_2 \Rightarrow 4.24 \sin\sin\theta = (1.00) \sin\sin 90°$ C1
$\theta = 13.6°$ A1

(iii) coating increase critical angle so more photons emerge / allows photons with larger angles to the normal of the surface of diode (that are otherwise trap in diode) to emerge M1

these photons (with those emerging perpendicularly) are then reflected by plastic bulb and concentrated in forward direction A1

so, more photons released for given energy input

(f) ratio = (900 / 9) / (840 / 60) M1

= 7.1 A1

NJC Preliminary Examination 2024
H2 Physics Paper 3

Solutions and Mark Scheme

Section A

1 **(a)** change in velocity of the body is always perpendicular to velocity when speed is constant. B1

acceleration and so resultant force [Newton's second] is always perpendicular to the velocity B1

velocity is tangent to circular path, so resultant force (perpendicular to the velocity) directed towards centre of circle B1

(b) **(i)** centripetal acceleration

$$= \frac{\left(\frac{25\times10^3}{60\times60}\right)^2}{7.0}$$ M1

$= 6.9 \text{ m s}^{-2}$ or 6.89 m s^{-2} A1

(ii) force on mass = 0.50 × 6.889 = 3.4445 N C1

displacement = 3.4445 × 5.0 = 17 mm or 17.2 mm A1

(iii) extension of spring at B > spring at A / spring at B is extended while spring at A is compressed to provide this resultant force (towards B or centre) M1

pointer moves towards A. A1

2 **(a)** The gravitational potential at a point is defined as the work done per unit mass in bringing a small test mass from infinity to that point. B1

(b) **(i)** Increase in potential energy = final potential energy – initial potential energy

$$= -\frac{GMm}{r_2} - \left(-\frac{GMm}{r_1}\right)$$

B1

$$= GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

1 mark for correct potential energy formula (**WITH negative sign**) and substituted correctly.

(ii) **Work is done by thrusters** M1

Hence **total** energy **increases** / **not constant** M1

Increase in potential energy not equal to decrease in kinetic energy A0

(c) Decrease in potential energy = increase of KE

$$0 - \left(-\frac{GM(m_r)}{r_2}\right) = \frac{1}{2}(m_r)v^2 - 0$$ or equate total energy

M1 for correct decrease in potential energy, M1 for correct increase in KE

$$v = \sqrt{\frac{2GM}{r_2}}$$

A1 for the correct final expression for v.

3 **(a)** **(i)** Kinetic energy of one gas particle (atom / molecule) = $\frac{1}{2}mc_{rms}^2 = \frac{3}{2}kT$
where m is the mass of one gas particle/atom/molecule. B1

For one mole of gas containing N_A particles, the total kinetic energy is given by:

$\frac{1}{2}N_A mc_{rms}^2 = \frac{3}{2}N_A kT$ ------------------ (1)

From the equation of state of an ideal gas for 1 mole of ideal gas:
$pV = (1)RT = N_A kT$ B1

Substituting $N_A kT = RT$ into (1) gives: $\frac{1}{2}N_A mc_{rms}^2 = \frac{3}{2}RT$

Simplifying to get: $c_{rms} = \sqrt{\frac{3RT}{N_A m}} = \sqrt{\frac{3RT}{M}}$

Where $N_A m$ is the mass of 6.02 x 10^{23} particles = molar mass M.

(ii) $c_{r.m.s.} \propto \frac{1}{\sqrt{M}}$ $\frac{c_{r.m.s.}\ of\ oxygen\ molecules}{c_{r.m.s.}\ of\ nitrogen\ molecules} = \sqrt{\frac{28}{32}} = 0.935$ or 0.94
A1

(b) **(i)** $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle = \frac{1}{3}\rho\langle c^2\rangle = \frac{1}{3} \times 1.50 \times 10^5 \times (4.85 \times 10^5)^2$ M1

= 1.18 x 10^{16} Pa A1

(ii) Forces between nuclei/particles are not negligible. (ignore "attractive") M1

Forces are repulsive (at that density) contributing to an increase in pressure A1

OR

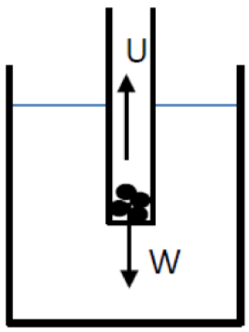
Volume of particles is not negligible (at that density) M1

Resulting in a higher <u>rate</u> (or <u>frequency</u>) of collision compared to the expected rate, causing the actual pressure to be higher than the expected value in (b)(i). A1

(c)

Process	w / kJ	q / kJ	⊗U / kJ
A to B	<u>19.2</u>	67.2	<u>– 48.0 [B1]</u>
B to C	0	<u>48.0</u>	<u>48.0 [B1]</u>
C to A	31.6	31.6	0

4 **(a)** **(i)**



W: Weight of loaded test-tube
or
W_L: weight of lead shots and W_T: weight of test-tube

U: Upthrust / Force by fluid on loaded test-tube

Legend for both W and U — B1

W and U of <u>same length</u> and act <u>along the same vertical line</u> — B1

(*Note that arrow of W should originate from C.G. of loaded test-tube while arrow of U should originate from centre of mass of the displaced fluid.)*

(ii) Summing forces vertically: $mg = Upthrust = \rho ALg$ — M1

mass of loaded test tube, $m = \rho AL$ — A1

(b) **(i)** Resultant force (in vector notation): F = Upthrust + Weight

$$F = -\rho A(L + x)g + mg = -\rho ALg + mg - \rho Axg$$ M1

Since $mg + (\rho ALg) = 0$ — M1

$$F = -\rho Axg$$ A0

(ii)

$$F = -\rho Axg = ma$$

$$a = -\left(\frac{\rho Ag}{m}\right)x$$ M1

$$= -\left(\frac{\rho Ag}{\rho AL}\right)x$$ M1

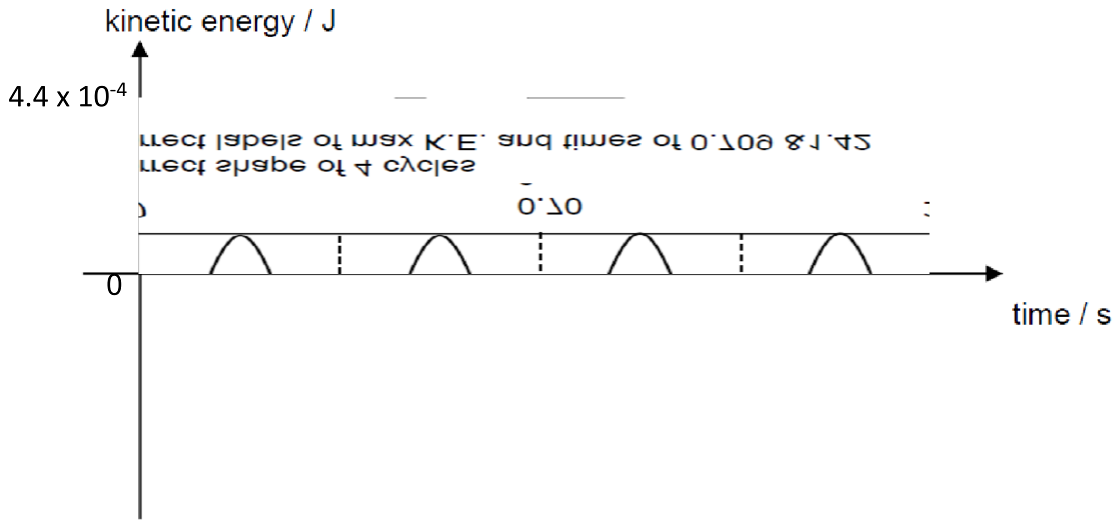
Since loaded test-tube is in SHM: $a = -\omega^2 x$ — M1

$\omega^2 = \frac{g}{L}$, so $\omega = \sqrt{\frac{g}{L}}$

(iii) Total energy $= \frac{1}{2} m \omega^2 x_0^2 = \frac{1}{2}(0.050)(9.81/0.125)(0.015)^2$ — M1

$= 0.00044$ J — A1

(iv)



correct shape ($\sin^2$ not modulus) of 4 "humps" with k.e. starting from zero B1

correct label of max K.E. B1

5 **(a)** **(i)** Waves from the two slits overlap and superpose (debrief point) at points on the screen B1

When path difference from slits to point is multiples of wavelength / phase difference between the two waves is multiples of 2π, constructive interference gives bright fringe B1

(ii)

$$\text{separation} = \frac{\left(590 \times 10^{-9}\right)(2.3)}{1.2 \times 10^{-3}}$$ M1

$= 1.1$ mm or 1.13 mm A1

(b) $sin\ sin\ \theta\ = \frac{\lambda}{b} = \frac{590 \times 10^{-9}}{0.31 \times 10^{-3}} \approx \frac{x}{D}$ must see sinθ M1

$(tan\ tan\ \theta\ = \frac{x}{D} = \frac{x}{2.3}$ led to $x = \frac{\left(590 \times 10^{-9}\right)(2.3)}{0.31 \times 10^{-3}}$

width = 2*x* M1

= 8.8 mm A0

(c) Diffraction minimum is (8.8 / 2 =) 4.4 mm from P and the fourth order bright fringe is (1.1 × 4 =) 4.4 mm from P B1

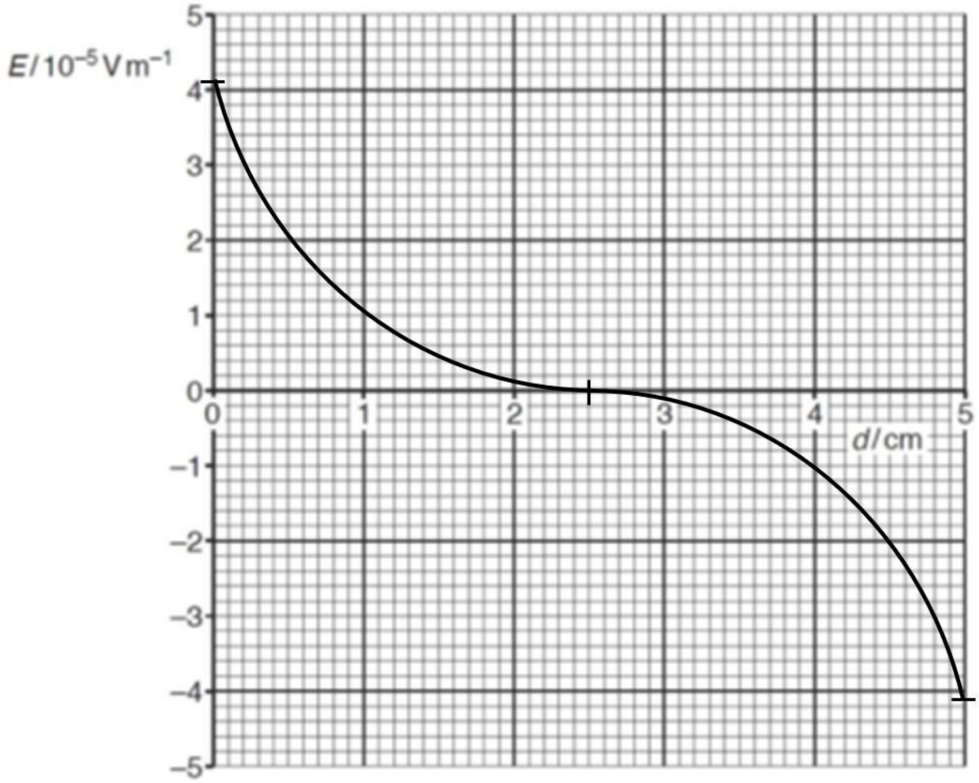
Position of 4th order interference maximum coincides/overlap with (first order) diffraction minimum. B1

6 **(a)** $E = Q / 4\pi\varepsilon_0 r^2$ or $E = kQ / r^2$ with k defined / substituted in

$4.1 \times 10^{-5} = [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.025^2)] - [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.075^2)]$ M1

$Q = 3.2 \times 10^{-18}$ C A1

(b)



correct shape (start positive E, gradient trend) B1

through points $(0, 4.1 \times 10^{-5})$ $(2.5, 0)$ & $(5.0, -4.1 \times 10^{-5})$ B1

(c) Using the graph, E-field strength on the left of d = 2.5 cm is positive, while on the right is negative. Thus, the graph shows E-field is always directed towards the d = 2.5 cm. B1

Electric Force, $F = qE$, (or acceleration) on positive charge is always opposite to displacement from d = 2.5 cm B1

7 **(a)** $V = 2.4\ V = V_p$
$N_s / N_p = 50 = V_s / V_p$ M1

$V_s = 2.4 \times 50 = 120V$
Max V_S $= 120 \times \sqrt{2}$
$= 170V$ A1

(b) $P_{ave} = ½ (½) P_0$

$= ¼\ V_0^2/R$

$= ¼\ 170^2 / 47$ C1

$= 154$ W A1

(c) $P_{new} = 2\ P_{ave} = 307$ W (allow ecf part b) M1

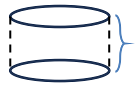
(d) Direct voltage since the voltage shown is always positive (w.r.t. time) B1

(e) Transformers requires an input voltage that varies with time. B1

Section B

8 **(a)** **(i)** Area cut in time ⊗t is the curved surface area of a cylinder traced out by the falling ring. $A = (2\pi r)(v\Delta t)$

Flux cut, $\Delta\Phi = BA = B(2\pi r)(v\Delta t)$ — B1



Comments: Some explanation is expected in the working since this is a "show" question. No credit for candidates who just write $\Delta\Phi = B(2\pi r)(v\Delta t)$

(ii) From Faraday's Law, induced e.m.f. $E = \dfrac{\Delta\Phi}{\Delta t}$

$$= \frac{B(2\pi r)(v\Delta t)}{\Delta t} = 2\pi rBv$$ M1

Induced current $I = \dfrac{E}{R}$ M1

$$= \frac{2\pi rBv}{R}$$

(iii) Magnetic force exerted by the radial magnetic field on the induced current in the ring, $F_B = BIL = B(\square)(2\pi r)$ M1

From Newton's 2nd Law: Resultant force on the ring $= mg - F_B = ma$ M1

$$mg - B\left(\frac{2\pi rBv}{R}\right)(2\pi r) = ma$$

$$a = g - \frac{(2\pi rB)^2 v}{mR}$$ A0

(iii) Maximum speed (when a = 0) is

$$v_{max} = \frac{mgR}{(2\pi rB)^2}$$ C1

$$= \frac{(0.0235)(9.81)(2.30\times10^{-4})}{(2\pi\times0.03\times0.800)^2}$$ M1

$= 2.33 \times 10^{-3}$ m s^{-1} A1

(iv)

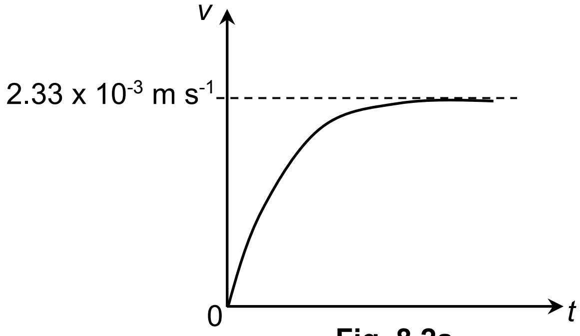


Fig. 8.2a

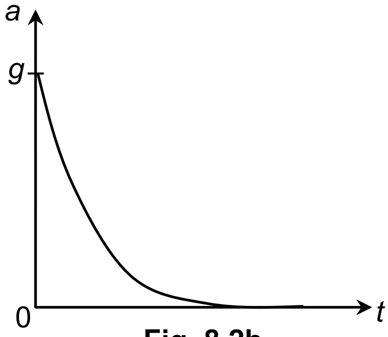


Fig. 8.2b

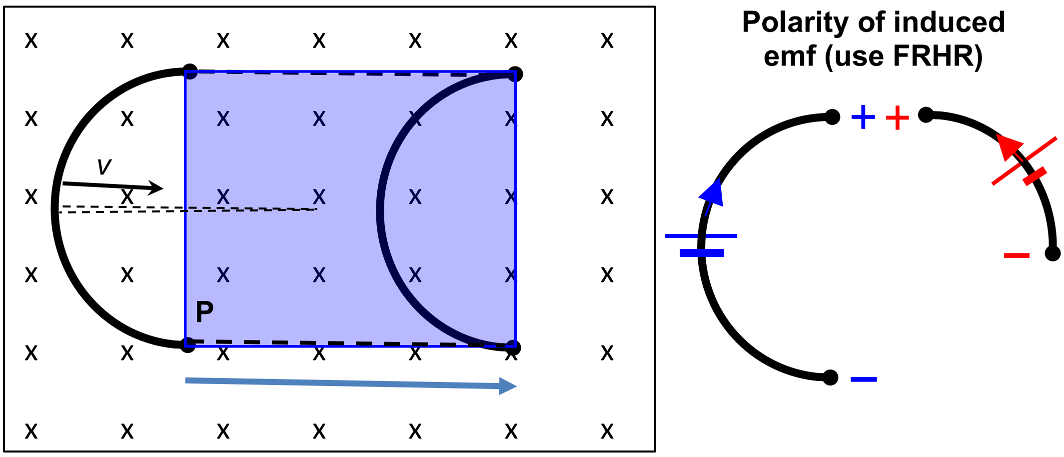
Correct shape B1
label terminal velocity B1
Correct shape for a-t graph B1

(b) **(i)** Induced e.m.f. = Brv = 0.500 x 0.03 x 0.03 M1

= 4.50 x 10^{-4} V A1

(ii) Q B1

Explanation for (i) above



Area cut/swept in time t is equal to the area of the shaded rectangle.

Induced emf for the semi-circle.

Induced emf for the quarter circle

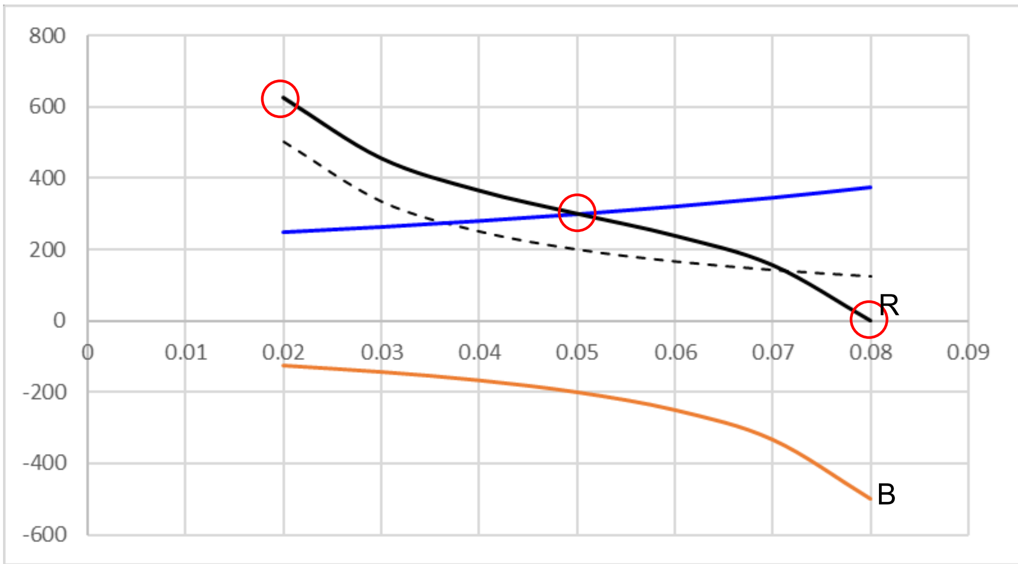
Net induced emf

(c) **(i)** Flux density due to the two conductors carrying 20 A will cancel at X leaving the resultant flux density $= \frac{\mu_0(90)}{2\pi \times 0.15}$ M1

= 1.20 x 10^{-4} T A1

Out of the page B1

(ii)



Correct shape and negative values for curve B B1
Correct shape for R B1
R must pass through 2 out of 3 circled points. B1

9 **(a)** **(i)** lowest frequency of electromagnetic radiation M1

giving rise to emission of electrons (from the surface) A1

(ii) threshold frequency = $(9.0 \times 10^{-19}) / (6.63 \times 10^{-34})$ M1

$= 1.4 \times 10^{15}$ Hz A1

(iii) *either*

frequency of radiation between 5×10^{14} Hz and 10×10^{14} Hz
or energy of photons between 3.3×10^{-19} J and 6.6×10^{-19} J
or threshold wavelength: zinc = 340 nm, sodium = 520 nm, platinum = 220 nm
M1

emission from sodium and zinc A1

(iv) **1.** photon interact with electron below surface M1

energy required to bring electron to surface A1

2. show threshold frequency is 5.8×10^{14} Hz
e.g extrapolate graph to intersect with *x*-axis
e.g chose a point (7.0, 0.5) and substitute into $E_{MAX} = \frac{h}{e}(f - f_0)$ M1

metal is sodium A1

(b) **(i)** **1.** centripetal force of orbiting electron provided by electric force acted by proton and so $\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$ M1

correct manipulation to obtain $\frac{1}{2}mv^2 =$ expression A1

2. $E_T = \frac{e^2}{8\pi\varepsilon_0 r} + \left(-\frac{e^2}{4\pi\varepsilon_0 r}\right)$ M1

$E_T = -\frac{e^2}{8\pi\varepsilon_0 r}$ A0

(ii) $\lambda = \frac{h}{\sqrt{2mE_K}} = \frac{h}{\sqrt{2m \times \frac{e^2}{8\pi\varepsilon_0 r}}}$ M1

$\lambda = \frac{h}{e}\sqrt{\frac{4\pi\varepsilon_0 r}{m}}$ A0

(iii) $E_T = -\frac{e^2}{8\pi\varepsilon_0 \times \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}} = -\frac{me^4}{8\varepsilon_0^2 h^2}\frac{1}{n^2}$ B1

$k = \frac{me^4}{8\varepsilon_0{}^2h^2} = \frac{\left(9.11\times10^{-31}\right)\left(1.60\times10^{-19}\right)^4}{8\left(8.85\times10^{-12}\right)^2\left(6.63\times10^{-34}\right)^2}$ M1

$k = 2.17\times10^{-18}\,J$ A1

(iv)

$$\lambda = \frac{hc}{\Delta E}$$

longest wavelength for transition from n = 3 to n = 2 and shortest wavelength from n = ∞ to n = 2 C1

correctly show longest wavelength is 660 nm M1

correct show shortest wavelength is 367 nm M1

so, Balmer series are visible A0

NJC Preliminary Examination 2024

H2 Physics Paper 4

Question	Marking points	Marks
1(a)	Value of R_A and R_B recorded to nearest 0.1 Ω m^{-1}.	1
1(b)(i)	Values recorded to nearest 0.1 cm with correct unit (cm).	1
	x > *y*.	1
1(c)	Six sets of readings of *x* and *y* including the data from **(a)** without assistance. Correct trend of increasing *x* and *y*	1
	Range: Smallest 20 cm ≤ *x* ≤ 30 cm and largest *x* ≥ 80 cm.	1
	Each column heading (*x*, y, $\frac{1}{x}$ and $\frac{1}{y}$) contains a quantity and a unit.	1
	All calculated values $\frac{1}{x}$ and $\frac{1}{y}$ must be given to the same number of significant figures as the raw values.	1
1(d)	Axes: ● Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions). ● Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. ● Axes must be labelled with the quantity which is being plotted. ● Scale markings should be no more than two large squares apart.	1
	Plotting of points: ● All observations in the table must be plotted on the grid. ● Diameter of plotted points must be ⩽ half a small square. ● Points must be plotted to an accuracy of half a small square in both the x and y directions.	1
	Line of best fit: ● Judge by balance of all points on the grid about the candidate's line (at least 6 points). There must be an even distribution of points either side of the line along the full length. ● Allow one anomalous point only if clearly indicated. There must be at least five points left after the anomalous point is disregarded. ● Lines must not be kinked or thicker than half a small square.	1
	Gradient: ● The hypotenuse of the triangle used must be greater than half the length of the drawn line. ● Method of calculation must be correct, i.e. Δy / Δx. ● Gradient sign on answer line matches graph drawn. ● Both read-offs must be accurate to half a small square in both the *x* and *y* directions.	1
	y-intercept: Check correct read-off from a point on the line and substituted into $y = mx + c$. Read-off must be accurate to half a small square in both x and y directions. **or** Intercept read directly from the graph at $x = 0$, accurate to half a small square.	1
	Value of *a* = gradient with no unit.	1
	Value of b = *y*-intercept with correct unit (cm^{-1} or m^{-1}).	1
1(e)	Correct calculation of Internal resistance *r* and *r* must be positive	1

Question	Marking points	Marks
2(b)(ii)	Value of θ recorded to the nearest degree with correct unit.	1
	$L \geq L_0$, expressed to 1 decimal place	1
2(c)	Value of *e* calculated from $L - L_0$.	1
	Correct calculation of *k*.	1
2(d)	*m* is varied to obtain angle θ, adjust the apparatus to keep the length of spring or extension of the spring fixed (and PQ horizontal) or *m* is varied to obtain extension of spring *e*, adjust the apparatus to keep θ fixed.	1
	Plot a graph of cos θ against *m* or Plot a graph of *e* against *m*	1
	State how *k* is calculated e.g. $k = g / (\cos\theta \times \text{gradient})$ or $k = g / (e \times \text{gradient})$	1

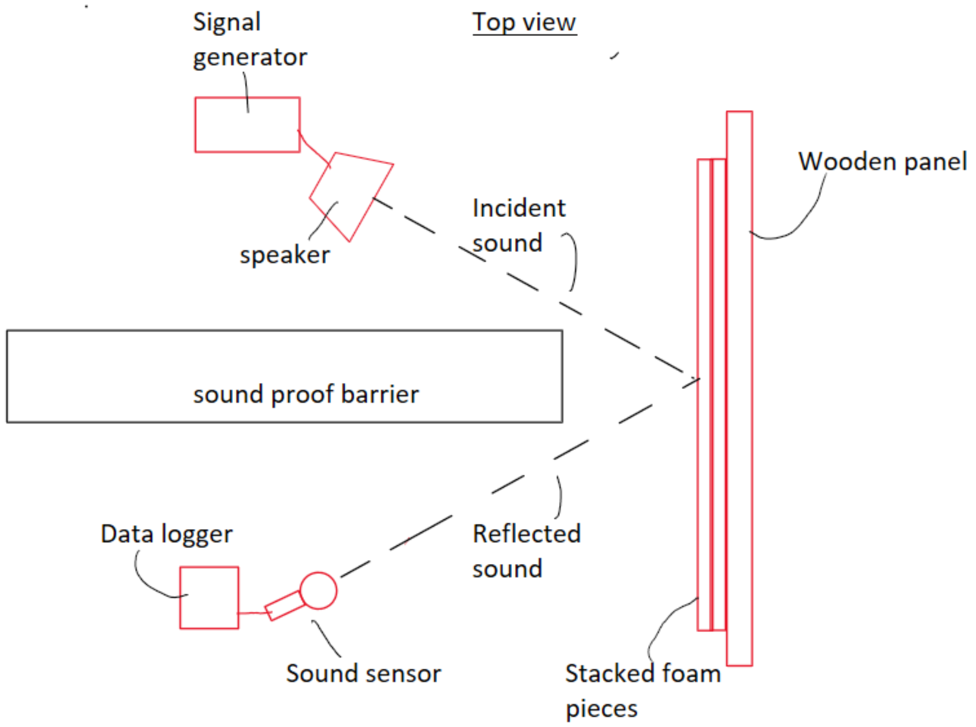
Question	Marking points	Marks
3(a)(ii)	0.30 mm ≤ *d* ≤ 0.32 mm.	1
	Evidence of repeat readings of diameter expressed to 0.01 mm.	1
3(a)(iii)	• Absolute uncertainty in *d* in range 0.01 mm (if repeated readings have been taken, then the uncertainty can be half the range (but not zero) if the working is clearly shown). • Correct method of calculation to obtain percentage uncertainty expressed to 1 s.f. or 2 s.f.	1
3(a)(iv)	*A* calculated correctly.	1
3(b)(iv)	Evidence of repeat readings of timings (repeat twice for timings ≥ 15 s, repeat thrice for 5 s ≤ timings ≤ 15 s).	1
	T expressed to the number of significant figures as the timings.	1
3(b)(v)	• Absolute uncertainty in timing in range 0.2 s – 0.5 s (if repeated readings have been taken, then the uncertainty can be half the range (but not zero) if the working is clearly shown). • Correct method of calculation to obtain percentage uncertainty expressed to 1 s.f. or 2 s.f.	1
3(c)(i)	0.14 mm ≤ *d* ≤ 0.16 mm.	1
	A calculated correctly.	1
3(c)(ii)	Second value of *T* > first value of *T*.	1
3(d)(i)	Two values of *k* calculated correctly, expressed to the least significant figures of values used, *k* correct unit (e.g. $cm^{1.5}$ s).	1

Question	Marking points	Marks
3(d)(ii)	Valid comment consistent with the percentage difference of the values of *k* and testing against the any one of the two percentage uncertainties in **(a)(iii)** and **(b)(v)**.	1
	Testing percentage difference of the values of *k* against percentage uncertainty = 2 × **(a)(iii)** + **(b)(iii)**.	1
3(e)(ii)	Varying of *m* with at least one reading of *T* greater and one reading smaller than T_S	1
	Reasonable method to approx. *m* eg. Sketch *T* against *m* as accurately as possible.	1
	m is approximated by showing *T* = T_S on the sketched graph.	1
	Note: When period T for different m is similar, candidate must have collected the data of swinging oscillation rather than torsional oscillation. This part will be awarded zero.	
3(f)	Measure diameter of mass with vernier callipers and state radius = diameter / 2. *Note: Micrometer screw gauge is not accepted because if r > jaw, instrument cannot be used.*	1
	Set up the apparatus and follow the procedure in **(a)** and **(b)** using mass of at least 6 different radii. Follow the procedure in **(a)(iii)** and **(b)** to determine the period *T* of the (torsional) oscillations.	1
	Keep *L* and *m* constant when repeating for different radii.	1
	Plot a graph of *T* against *r* or *r* against *T* and state proportionality shown when a straight line through origin obtained.	1
	Very small radii has very short period (and difficult to count the number of oscillations). To keep the mass constant, large radii means that the mass must be very thin or very large radii has very long period (and difficult to ascertain the completion of one oscillation).	1

Question 4 marking points		Marks
D1	**Diagram** ● <u>Labelled</u> diagram, <u>drawn with ruler</u>, with <u>either a table or indicated as top view</u>. ● Equipment must not be “floating”. ● Diagram must include speaker, foam, wooden panel ● Diagram include the apparatus mentioned in the procedure e.g. speaker connected to signal generator, sensor/ microphone/ receiver, CRO, data logger etc.	1
M1	**Methods + Instruments to measure dependent variable** Measure intensity I (or amplitude) of reflected signal using sound meter or microphone connected to CRO or data logger / sound sensor or sound intensity sensor connected to data logger. The following are not accepted: “power sensor”/ “intensity sensor”	1
M2 M3 M4 M5	**Methods + instruments to measure independent.** **Procedure 1** <u>Vary frequency f with signal generator, t fixed</u> f <u>read directly from signal generator</u> (must mention) or calculate using <u>f = 1/T</u> and measure <u>T from c.r.o.</u> or <u>sound sensor connected to data logger</u>. Note: sound meter/sound intensity meter only measures intensity in dB (unless connected to data logger). Do not accept measurement of frequency using sound meter. **Procedure 2** <u>Vary thickness by stacking the foam pieces, fix f</u> Measure the <u>thickness of foam</u> with a <u>rule/ micrometer/ vernier calipers</u>.	4
C1	**Control of variables** ● Speaker at fixed angle and cannot be normal to the panel ● Fixed distance between speaker to foam and foam to microphone ● Fixed speaker output (loudness, intensity, etc)	1
A1 A2	**Method of analysis** <u>Procedure 1:</u> Plot a graph of lg I vs lg f with gradient is y. <u>Procedure 2:</u> Plot a graph of lg I vs lg t with gradient is x.	2
P1	**Procedure to reduce interference** Valid methods to reduce interference (shown either in procedure or indicated in the diagram) e.g. shielding between speaker and sensor (NOT sound-proof room) or position of sensor ‘behind’ speaker at sufficiently wide angle such that no interference from speaker.	1
	Additional detail and/or safety precaution (max 2 marks)	
AD1	Preliminary reading to ensure intensity can be read by sensor (without distortion) and varied by procedure	
AD2	Details on how to arrange angle of microphone to maximise the intensity measured	
AD3	Repeat and average the measurement of thickness of foam	
AD4	Measure background intensity and subtract from data	
AD5	Precaution linked to loud sounds, e.g. use ear plugs/muffs/defenders.	
Designs that are penalised		

1. Experiment that does not yield meaningful data e.g. using stationary wave approach (speaker and microphone along the same line to screen), microphone in front of speaker, microphone directly behind speaker.	**max 3 marks**
2. If the dependent variable cannot be measured reasonably e.g. no sensor, completely wrong sensor, no marks should be awarded for M1, A1 and A2	**max 9 marks**
3. If speaker is used without reasonable means to control frequency (e.g. without signal generator), no marks should be awarded for M2, M3 and A2	**max 9 marks**

Suggested solution for Q4



Procedure:

lg I = lg A + x lg t + y lg f

Expt 1: lg I against lg t, gradient = x
Expt 2: lg I against lg f, gradient = y

Setup instructions

Set up the experiment as shown in the diagram above.

Conduct preliminary experiments to adjust the angle of the speaker and sound sensor to obtain the loudest intensity of the reflected sound. Throughout both experiments described, ensure the following:

- keep the angle determined from preliminary data the same,
- speaker, foam pieces, wooden panel and sound sensor are kept at the same positions so that the distance between the speaker and foam pieces, sound sensor and foam pieces are constant,
- volume of the speak or the amplitude/intensity setting of the signal generator is kept constant.

Incident sound from speaker may reach sound sensor, to minimise such interference:

- position sound sensor slightly behind the speaker so that incident sound reaching sensor minimised,

- place sound proof barrier between the speaker and the sound sensor.

To improve accuracy, measure the average background sound intensity. The intensity I of the sound used in the analysis for the two experiments are obtained by subtracting the background value from the measured intensities.

Experiment 1

1. Measure the thickness t_1 of each of the provided identical pieces of foam using vernier calipers at different places and take average. To vary thickness, stack the foam pieces and use $t = Nt_1$ to determine thickness of the stacked foam pieces. (Alternative, measure after stacking at different places and take average)
2. Using the signal generator connected to the speaker, use a frequency that can be detected by the sound sensor. Keep this frequency of sound constant for this experiment. Frequency f is read directly from signal generator.
3. Measure and record the intensity I of the reflected signal using the sound sensor connected to the data logger.
4. Vary the thickness of the foam pieces and measure the intensity of the reflected signal for another 9 sets of readings. Tabulate the data.
5. Plot a graph of lg I against lg t, the gradient of the graph is x.

Experiment 2

1. Use just one piece of foam for this experiment. Measure the thickness of the foam.
2. Adjust the signal generator to vary frequency. Obtain the frequency f of the sound wave directly from the signal generator and record this value.
3. Measure the intensity I using the sound sensor connected to data logger.
4. Repeat for a total of 10 different values of frequencies, obtaining intensity of reflected wave for each frequency. Tabulate the data.
5. Plot a graph of lg I vs lg f, the gradient of the graph is y.

Safety precaution
To protect your hearing, ear muffs should be worn when the speaker is switched on.