2022 H2 Prelim Paper 1 Solutions:

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

1 B $C_d = \frac{2F}{v^n \rho A} \Rightarrow C_d v^n \rho A = 2F$

Unit of v = m s^{-1}

Unit of ρ = kg m^{-3}

Unit of A = m^2

Unit of F = kg m s^{-2}

$\Rightarrow$ 1 × kg $m^{n-1}s^{-n}$ = kg m s^{-2}

$\Rightarrow$ n = 2

2 D Radius of the object = $\frac{0.12}{6.4\times10^6}\times1.7\times10^6 = 0.032$ m = 3.2 cm

3 A Velocity of motorcyclist relative to car, $V_R = V_M - V_C$

4 C Separation between P and Q is maximum when P is just hitting the ground.

Time for P to reach the ground is given by:

$s = ut + \frac{1}{2}gt^2$

$= \frac{1}{2}gt^2$

$80 = 5t^2$

$t = 4$ s

Position of Q when P is hitting the ground:

$s = u(t-1) + \frac{1}{2}g(t-1)^2$

$= \frac{1}{2}g(t-1)^2$

$= 5\times(4-1)^2$

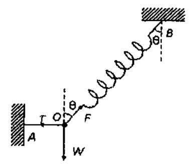
= 45 m

Hence, max. separation between P and Q = 80 – 45 = 35 m

5 D As the object is in static equilibrium, the resultant force of the three external forces acting on the object is equal to zero.

i.e. $\vec{T} + \vec{F} + \vec{W} = 0$

and $\vec{F} + \vec{W} = -\vec{T}$



vertical: $F \cos\theta = W = mg$

horizontal: $F \sin\theta = T$

$\Rightarrow T = mg \tan\theta$

At the instant the thread is suddenly cut, the force $\vec{T}$ is removed. Resultant force acting on the object $= \vec{F} + \vec{W}$ $= -\vec{T}$

Hence, acceleration of the object is direction II and magnitude of acceleration = $g \tan\theta$

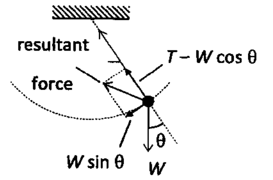
6 B Total momentum of wagon remain unchanged because the vertical force by rain does not affect the horizontal momentum of the wagon.
The horizontal speed of wagon decreases because the amount of water in the wagon increases which increases the total mass of the system and so horizontal speed will decrease.

The kinetic energy of the system decreases using the equation ke = $\frac{p^2}{2m}$ since m increases while p remain constant.

7 C The 3 forces, the 2 tensions in the string and the weight of the rod need to intersect at a point for it to be in equilibrium.

8 C Driving power = driving force x velocity = 500 x 40 = 20 MW
Power lost due to air resistance = air resistance x velocity = 200 x 40 = 8 MW
Rate at which kinetic energy is increasing = 20 – 8 = 12 MW

9 B



As the bob undergoes circular motion, there must be a resultant force acting on the bob in radial direction = centripetal force
= $T - W \cos\theta$

In the tangential direction, resultant force acting on the bob = $W \sin\theta$
Hence, the resultant force should be in direction Q.

10 A At the bottom of the hill, the net force = N - mg = centripetal force = ma
Hence, N = mg + ma > 0.
Therefore, the car can never lose contact at the bottom of the hill.

At the top of the hill, the net force = mg – N = ma
Hence, N = mg – ma
Therefore, the car will lose contact (feel weightless) when N < 0

$\Rightarrow g < a$

$\Rightarrow g < \frac{v^2}{R}$

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$\Rightarrow v > \sqrt{gR}$

11 D $E_i = E_f$

$\frac{1}{2}mv_e^2 + \left(-\frac{GMm}{R}\right) = 0 + 0$

$v_e = \sqrt{\frac{2GM}{R}} \propto \sqrt{\frac{M}{R}}$

12 C $W_{ext} = m\Delta\phi$

$50 = 2.0(\phi_B - \phi_A)$

$\phi_B - \phi_A = 25$ J kg^{-1}

$W_{ext} = m\Delta\phi$

$-60 = 2.0(\phi_C - \phi_B)$

$\phi_C - \phi_B = -30$ J kg^{-1}

$W_{ext} = m\Delta\phi$

$1000 = 2.0(\phi_\infty - \phi_C)$

$\phi_C = -500$ J kg^{-1}

$\therefore \phi_B = -470$ J kg^{-1} and $\phi_A = -495$ J kg^{-1}

13 A Using $Q = mc\Delta\theta$,

Rate of heat removed is $\frac{Q}{t} = \frac{m}{t}c\Delta\theta$

$\Rightarrow \frac{m}{t} = \frac{\left(\frac{Q}{t}\right)}{c\Delta\theta} = \frac{\left(\frac{4.0\times10^{11}}{60\times60}\right)}{4200\times8} = \frac{4.0\times10^{11}}{4200\times8\times60\times60}$ kg s^{-1}

14 C For the grain of sand,

At eqm: a = 0
N = mg

At $x = +x_o$,
mg – N = ma
N = mg – ma = mg – mg = 0

At $x = -x_o$,
N – mg = ma
N = mg + ma = mg + mg = 2mg

15 D $x = x_0 \sin\omega t$

$= 3.0\sin\left(\frac{2\pi}{2.0}\right)0.25$

$= 2.1$ m

Total distance travelled = 3.0 + 2.1 = 5.1 cm

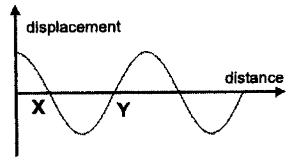
16 A *phase difference* $= \frac{0.22\sin25^\circ}{1.7} \times 2\pi = 0.34$ *rad*

17 C

A is incorrect — At X, the air pressure is maximum

B is incorrect — It is a progressive wave not a standing wave.

C is correct — At X, the air molecule is moving to the right.



D is incorrect — At Y, equilibrium position, the air molecule has the highest speed.

18 C $f = \frac{v}{d}$

$10 = \frac{2.0}{d}$, $d = 0.20$ m

$\lambda = 2d = 0.40$ m

Distance moved from initial position at M to second minimum intensity = 3(1/4 λ) = 0.30 m

19 A ke = $\frac{1}{2}mv^2 \propto v^2$

using $v^2 = 0 + 2ax$ $\Rightarrow v^2 \propto x \Rightarrow v \propto \sqrt{x}$ and ke $\propto x$, so quantity *Y* is speed *v*

E field is uniform inside the parallel plates, electric force is constant.

Electric potential energy, U =eV decreases linearly with *x* since e is negative and V is increasing linearly from -V to 0.

20 C

By potential divider method, the p.d. across internal resistance is $E\frac{\left(\frac{r}{2}\right)}{R+\frac{r}{2}} = E\frac{r}{2R+r}$

Fraction of Power = $\frac{P_r}{P_{total}} = \frac{IV_r}{IV_{total}} = \frac{V_r}{E} = \frac{r}{2R+r}$

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21 **B** D_1 is reversed biased, so pd across it is -E and pd acorss R_1 is 0 V

22 **D** For steady current,

$P = I^2R$

For half – wave rectified ac,

$P = \left(\frac{I_o}{2}\right)^2\left(\frac{1}{2}R\right) = I^2R$

$I_o = \sqrt{8}I = 2.8I$

23 **B** By right hand grip rule, magnetic flux density at O due to P and Q points in direction of C.
Magnetic flux density due to R and S points in direction of A.
Hence resultant magnetic flux density at point O is in direction of B.

24 **A** The point charge's velocity is parallel to resultant magnetic flux density at the centre of the two wires. Thus magnetic force is zero.

25 **D** $\varepsilon = \frac{(2)(50)(30\times10^{-4})(4.0\times10^{-4})\sin 60^0}{0.60}$

$= 1.7\times10^{-4}$ V

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 **D** Velocity decreases → de Broglie's wavelength increases → sin θ increases→ larger diameter of circles

28 **B** Using Einstein's Photoelectric Equation,

hf $= \Phi + eV_s$

$3.5 \times 10^{-19} = \Phi + (1.6 \times 10^{-19})(0.25)$

$\Phi = 3.1 \times 10^{-19}$ J

29 **C** Total BE before reaction = 7.59 (235) = 1783. 65 Mev
Total BE after reaction = (8.26 x 121) + (8.52 x 113) = 1962 MeV
Change in BE = +179 MeV, manifested as the energy released (products are more stable)

30 **B** $\frac{A - X}{A_0 - X} = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$

$\frac{34 - X}{100 - X} = \left(\frac{1}{2}\right)^{\frac{20}{10}} = \frac{1}{4}$

$X = 12$ Bq

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H2 Physics Prelim 2022 Solutions

1 (a) Thrust = resistive force since velocity is constant. C1

Power = $Fv = Dv$

$D \times 15 = 90000$

$D = 90000/15 = 6.0$ kN A1

(b) F = Thrust Power = Fv

$F - D = ma$

$P/v - D = ma$

$120000/15 - 6000 = 800a$ M1

$a = 2.5$ m s^{-2} A1

(c) As the velocity increases with time, the resistive force also increases. B1
The driving force decreases as the speed of the boat increases since driving power stay constant, the net force on the boat decreases and hence acceleration decreases with time. B1 B1
Acceleration drops to zero when the resistive force is equal to the driving force on the boat. B1

2 (a)(i) Gravitational force provides centripetal force. Same gravitational force acting on star and planet.

$F_G = m_p r_p \omega^2 = m_s r_s \omega^2$ C1

$2.0\times10^{27}(r_p) = 6.0\times10^{28}(r_s)$

$\frac{r_s}{r_p} = \frac{2.0\times10^{27}}{6.0\times10^{28}} = \frac{1}{30}$

$r_s = \frac{1}{31}\times5.2\times10^9 = 1.68\times10^8$ m A1

(a)(ii) $F_G = F_C$

$\frac{Gm_s m_p}{d^2} = m_s r_s \omega^2$

$\frac{Gm_s m_p}{d^2} = m_s r_s\left(\frac{2\pi}{T}\right)^2$ C1

$\frac{6.67\times10^{-11}(2.0\times10^{27})}{(5.2\times10^9)^2} = (1.68\times10^8)\left(\frac{2\pi}{T}\right)^2$

$T = 1.16\times10^6$ s A1

(a)(iii) Planet moves in front of star periodically. A1

(b)(i) Between starting height 6.40×10^6 m & ending height 7.225×10^6 m

$g = (-)\frac{d\phi}{dr}$

$\Delta\phi = \int g\, dr$

$= $ area under g-r graph C1

$= 6.74\times10^6$ to 7.61×10^6 J kg^{-1} M1

$\Delta U = m\Delta\phi = 2300\,\Delta\phi$ M1

$= 1.55 \times 10^{10}$ to 1.75×10^{10} J

OR

$g = G\frac{M}{r^2}$ and $\phi = -G\frac{M}{r} \Rightarrow \phi = -gr$ C1

$\Delta U = m\Delta\phi = m(\phi_f - \phi_i) = 2300(g_i r_i - g_f r_f)$ M1

$= 2300(-9.75\times6.4\times10^6 + 7.625\times7.225\times10^6)$ M1

$\approx 1.60 \times 10^{10}$ J

(b)(ii) $\Delta U = U_f - U_i = -\frac{GM_E m_s}{r_f} - \left(-\frac{GM_E m_s}{r_i}\right)$

$1.6 \times 10^{10} = 6.67\times10^{-11} M_E (2300)\left(\frac{1}{6.40\times10^6} - \frac{1}{7.225\times10^6}\right)$ C1

$M_E = 5.85\times10^{24}$ kg A1

(b)(iii) Advantages to low polar orbit:
- High(er) resolution imaging/clearer images A1
- Image more of the planet as the Earth spins underneath the satellite

Geostationary:
- **Remain at the same position in the sky so satellite dishes can keep locked on to signal/no steerable dishes needed/send & receive signals all the times/continuous/uninterrupted/stable signals** A1
- Higher orbit means greater coverage of the signals

3 (a) angular speed of grating, ω = 2 π / T = 2 π / 3.0 = 2.1 rad s$^{-1$} A1

(b) The peaks represent the positions of constructive interference/maxima. B1

B1

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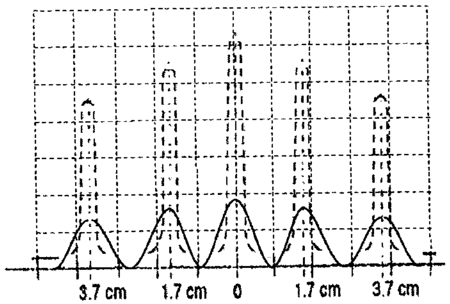
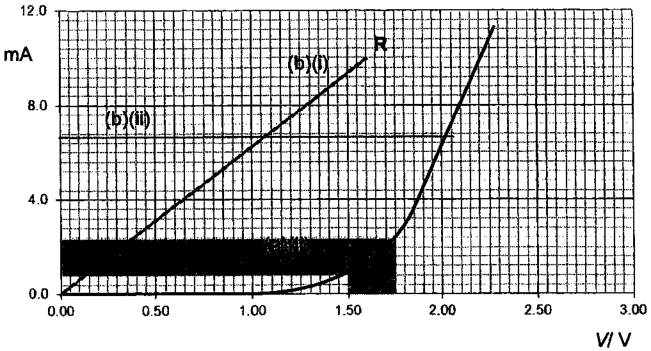
The effect of diffraction through the slits of diffraction grating causes interference fringes of higher order to have lower intensity than the zeroth order maxima.

(Peak C corresponds to the zeroth order of the diffraction pattern whereas peaks B and D the first order and Peaks A and E the second order.)

(c) (i)	Time interval = 3.7 x 0.1 = 0.37 s	C1
	$\theta = \omega t$ = 2.1 x 0.37 = 0.78 rad (ecf)	A1
(c)(ii)	Using the grating equation n λ = d sin θ, d = 1 x 10^{-3} / 550	C1
	sin θ_2 = 2 x 5.5 x 10^5 x λ	
	λ = 640 nm (ecf)	A1
(c)(iii) 1	Peak E is preferred as the angle θ is larger so the percentage uncertainty for calculating the wavelength is smaller.	C1
(c)(iii)2	From n λ = d sin θ	
	n < d/λ = 1 x 10^{-3} / 550 x 640 x 10^{-9} = 2.8	C1
	Hence, the highest order observed is 2nd order maxima.	C1
	Total number of orders observed = 2n +1 = 5	A0
(d)	Diagram must show that since the slit separation remains the same, the fringe separation remains the same. Peaks are less intense (poorer contrast) and less sharp (broader and less defined).	M1



4 (a) (i)	2.25/0.0108 = 208 Ω	C1
(a)(ii) & (b) (i)		



	(a)(ii) correct area shaded	B1
	(b)(i) Line R should be a straight line passing through (0,0) and (1.60 V, 10.0 mA)	M1
(b) (ii)	Draw a horizontal line on Fig. 4.1 such that the pd across 160 Ω and LED1 adds up to 3.0 V.	B1
	I = 6.2 mA	A1
(iii)	With two LEDs, effective resistance of the circuit is lowered,	B1
	leading to higher current from battery.	B1
	With higher current, the potential difference across the 160Ω resistor is larger, leaving less potential difference across the LEDs.	B1
	OR	
	With two LEDs in parallel, effective resistance between the LEDs is lowered.	
	By Potential Divider Principle, the potential difference across each LED is also lowered.	
	From the graph, it can be seen the current decreases with voltage, so the power (P=VI) dissipated in each LED is lower, so brightness is dimmer.	

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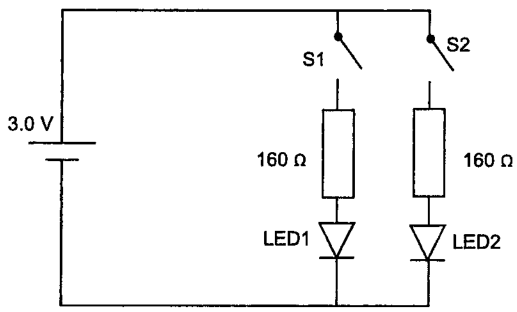
(c) **B1**



5 a DERQ and CFSP [B1]

bi As current flows through the slice in the presence of the magnetic field, it will experience a magnetic force to the left, by Fleming Left Hand rule. Hence a potential difference is generated across DERQ and CFSP.

When the current is undeflected at equilibrium, force on charge due to magnetic field equals force due to electric field [B1]

Bqv = Eq [B1]

E = B v

Electric field across faces DERQ and CFSP is constant

E = V_H / *d*, *where d is the distance between faces DERQ and CFSP* [A1]

$V_H = Bvd$

bii since $I = nAqv$ **where** [M1]

A is the cross-sectional area through which current flows, A= *dt* , *and t is the distance between faces CDEF and PQRS.*

$$v = \frac{I}{n(dt)q}$$ [C1]

$$V_H = (Bd)\left(\frac{I}{n(dt)q}\right) = \frac{BI}{ntq}$$ [A0]

biii For copper, *n* is very large hence V_H is very small, making it difficult to measure. [B1]

6 ai The *magnetic flux density at a point* is defined as the force acting per unit current per unit length on a current carrying conductor **M1**

when the conductor is placed at right angles to the magnetic field. **B1**

aii As AB moves from P towards Q, magnetic flux linkage over the area ABCD enclosed by the frame increases resulting in an induced e.m.f. generated in the frame by Faraday's law. **B1**

Since the frame is a conductor, induced current flows. By Lenz's Law, the induced current flows in an anticlockwise direction. **B1**

This results in a magnetic force that acts on AB towards the left which oppose motion. Hence the frame slows down. **B1**

Alternative:

As AB moves from P towards Q, magnetic flux linkage over the area ABCD enclosed by the frame increases resulting in an induced e.m.f. generated in the frame by faraday's law. **B1**

Frame is a closed circuit so induced current will flow in the frame. By conservation of energy, KE of the frame is converted to heat energy. **B1**

Energy is loss as P= I^2R. Hence frame slows down **B1**

aiii As AB enters the field, the increase in magnetic flux (linkage) $\Phi = BA = B(wx)$ where *x* is the distance AB has moved past P. **B1**

Hence, the magnitude of induced emf is given by $E = \frac{d\Phi}{dt} = Bw\frac{dx}{dt} = Bwv$ **B1**

Induced current that flows in the frame, $I = \frac{Bwv}{R}$ **B1**

Magnetic force which acts on AB is in opposite direction to motion is the braking force which slows the frame. **B1**

Braking force is thus $F = BIw = \frac{B^2w^2v}{R}$ **A0**

bii Distance **2*L*** = Area under *v* – *t* graph

= ½ (26 + 16 x 2 + 10 x 2 + 6 x 2 + 3.5)(5) **C1**

= 234 m

PQ = *L* = 117 m, Accuracy: L = 105 to 129 m **A1**

biii Braking force only acts on the train when there is a changing magnetic flux through the frame. There is no braking force on the train when the whole frame is within the magnetic field. **M1**

Increasing the length PQ does not change the exit speed. **A1**

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7(a)(i)	$I = \frac{P}{S} \Rightarrow P = IS$	C1
	$P = 5.0\times10^{2}\left(2.6\times10^{14}\right)$	A1
	$= 1.3\times10^{17}$ W	
(a)(ii)	1.3×10^{17} W	A1
(a)(iii)	$I = \frac{P}{S} = \frac{P}{4\pi r^2}$	M1
	$= \frac{1.3\times10^{17}}{4\pi\left(6400\times10^{3}\right)^{2}}$	M1
	$= 253$ W m^{-2}	A0
(b)(i)	x-axis marked with an arrow labelled M at 900-1100 nm	B1
(b)(ii)	$\lambda_{max}T = k$	
	$1000(2900) = k$	C1
	$k = 2.9\times10^{6}$ nm K	A1
(b)(iii)	$\lambda_{max}\ T = 2.90 \times 10^{6}$ nm K	
	Sun: $\lambda_{max} = 2.90 \times 10^{6} / 5800 = 500$ nm	A1
	Earth: $\lambda_{max} = 2.90 \times 10^{6} / 290 = 10000$ nm	A1
(b)(iv)	Sun's curve always above the original curve and peak at 500 nm	B1
(c)(i)	Radiation window – range of wavelengths which are transmitted/not absorbed by CO_2	B1
(c)(ii)	At 11000 nm, CO_2 absorbs close to 100% of radiation, so it is not a radiation window	B1
(d)	Sun's peak intensity in the 500 nm visible range. Energy radiated by Sun is able to pass through atmosphere as it is within the radiation window.	B1
	The visible light that reaches Earth is absorbed and re-radiated.	B1
	Earth's peak intensity is in the 10000 nm infrared range. Energy radiated by Earth is trapped by carbon dioxide as it is not in radiation window.	B1
	This leads to increase in temperature within the atmosphere.	
(e)(i)	$m = \rho V \Rightarrow v = \frac{m}{\rho}$	C1
	$v = \frac{2.8\times10^{18}}{1.0\times10^{3}} = 2.8\times10^{15}\ m^{-3}$	A1
(e)(ii)	Ice floats thus upthrust = weight of ice. And upthrust equals weight of displaced sea water. When ice melts, melted ice water only occupies the same volume as submerged part of ice pack	M1
	Hence no change to sea level.	A1

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JC2 H2 Physics Prelim Solutions P3

1 (ai) Internal energy is determined by the state of the system and it can be expresses as the sum of a random distribution of kinetic energy associated with the molecules of the system. [B1]

(ii) $pV = NKT$

$(1.05 \times 10^5) \times (2.9 \times 10^{-4}) = N \times (1.38 \times 10^{-23}) \times (303)$ [M1]

$N = 7.282 \times 10^{21} = 7.28 \times 10^{21}$ [A1]

(iii) $E_K = \frac{3}{2}kT$

$= \frac{3}{2} \times (1.38 \times 10^{-23}) \times (303)$

$= 6.272 \times 10^{-21} = 6.27 \times 10^{-21}$ J [A1]

(b) (i) $\Delta U = \frac{3}{2}Nk\Delta T$ [M1]

$= \frac{3}{2}(7.282 \times 10^{21})(1.38 \times 10^{-23}) \times (357 - 303)$ [A1]

$= 8.14$ J

Allow e.c.f. from aii

(ii) Since gas A undergoes an adiabatic compression, $Q = 0$.

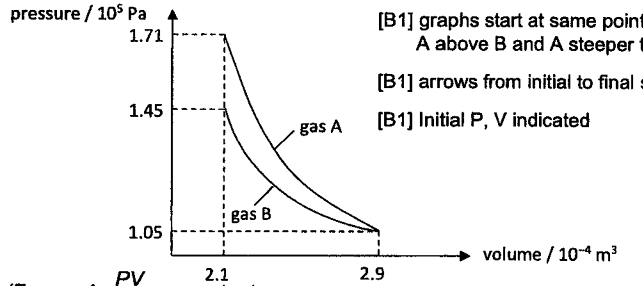
From the 1st law of thermodynamics,

$\Delta U = Q + W$

$8.14 = 0 + W$

$W = 8.14$ J [A1]

(iii)



[B1] graphs start at same point, with A above B and A steeper than B

[B1] arrows from initial to final state.

[B1] Initial P, V indicated

(For gas A, $\frac{PV}{T}$ = constant.

$\frac{1.05 \times 10^5 \times 2.9 \times 10^{-4}}{303} = \frac{p_A \times 2.1 \times 10^{-4}}{357} \Rightarrow p_A = 1.71 \times 10^5$ Pa

For gas B, PV = constant.

$(1.05 \times 10^5) \times (2.9 \times 10^{-4}) = p_B \times (2.1 \times 10^{-4}) \Rightarrow p_B = 1.45 \times 10^5$ Pa)

2	(a)	The acceleration of the particle is proportional to its displacement from the equilibrium position and is always directed towards that position.	B1 B1
	(b)	At $y = 0.000$ m, $TE = KE + GPE + EPE$ $= 0 + 0 + 0.445$ $= 0.445$ J *-Accept answer between 0.440 J and 0.445 J.*	C1 A1
	(c)	Straight line passing through the origin and (0.393, 0.160). *1. At $y = 0.160$ m, $TE = KE + GPE + EPE$* *$0.445 = 0 + GPE + 0.049 \Rightarrow GPE = 0.396$ J* *Acceptable value for the GPE at y = 0.160 m ranges from 0.390 J to 0.396 J.* *2. Students who draw curves get zero mark.*	B1 B1
	(d)	<u>Method 1:</u> Consider (0.393, 0.160) on *GPE* line,	

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BP~557

		$mg\,(0.160) = 0.393$ $m = 0.250$ kg Method 2: At $y = 0.080$ m, the equilibrium position of the SHM, extension e of spring is 0.040 m. (See Fig. 4.1). There is no net force on m, thus $ke = mg$ $(61.4)(0.040) = m\,(9.81) \Rightarrow m = 0.250$ kg	C2 A0
	(e)	Method 1: $KE_{max} = \frac{1}{2}mv_o^2 = \frac{1}{2}m\omega^2 x_o^2 \quad \Rightarrow \quad 0.196 = \frac{1}{2}(0.250)(\frac{2\pi}{T})^2(0.080)^2$ $T = 0.401$ s Method 2: $\omega^2 = \frac{k}{m}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{k}{m}$ $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.25}{61.4}} = 0.401$ s Method 3: At $y = 0.000$ m, the extension of spring is maximum, $e_{max} =$ 0.120 m. The mass is at its amplitude position in its SHM, so displacement is $x_o =$ 0.080 m. (See Fig. 4.1). $\uparrow$+: $F_{net} = ma \quad \Rightarrow \quad ke_{max} - mg = ma_o$ $ke_{max} - mg = m(\omega^2 x_o)$ $(61.4)(0.12) - (0.25)(9.81) = (0.25)(\omega^2\,(0.08))$ $T = \frac{2\pi}{\omega} = 0.401$ s	C1 A1

3 (a)

$F = qE = q\frac{\Delta V}{d}$

$1.12\times10^{-16} = 1.6\times10^{-19}\,\frac{\Delta V}{0.10}$ [C1]

$\Delta V = V_A - 0 = 70.0\ V$

$V_A = 70.0$ V [A1]

(b)(i) Gain in PE = Loss in K.E. of electron

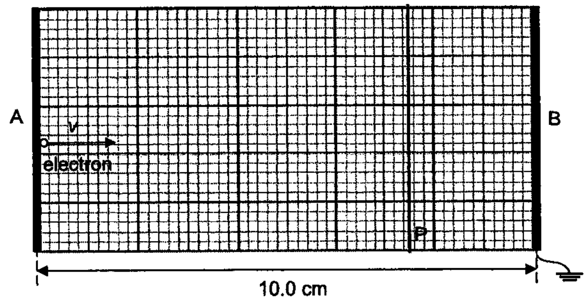
$q\Delta V = \frac{1}{2}mv^2$ [C1]

$-1.6\times10^{-19}\Delta V = \frac{1}{2}\times9.11\times10^{-31}\times(4.30\times10^{6})^2$

$V_P - 70 = -52.6$ V [A1] (ecf)

$V_P = 17.4$ V

(b)(ii)



(b)(ii) E = ΔV/d = 70/10 = 7.0 V cm^{-1}

∴ for ΔV = 52.6 V, d = 52.6/7.0 = 7.5 cm [C1] (ecf)

Draw a vertical line 7.5 cm from plate A [M1]

(c) The electron will stop **before** the equipotential line as the horizontal component of velocity in the direction of the field would be lower. [A1]

(d)(i) $F = ma = qE$

$1.67\times10^{-27}a_y = 1.6\times10^{-19}\times2.0\times10^{4}$

$a_y = 1.92\times10^{12}\,m\ s^{-2}$

$s_y = \frac{1}{2}a_y t^2$

$\frac{1}{2}(0.50\times10^{-2}) = \frac{1}{2}(1.92\times10^{12})t^2$

$t = 5.1\times10^{-8}\,s$ [C2]

$s_x = u_x t = 3.5\times10^{6}\times5.1\times10^{-8} = 0.179\ m$ [A1]

(d)(ii) $a_{proton} = qE / m$

$a_{alpha} = 2qE / 4m = ½\, a_{proton} = 9.6 \times 10^{11}$ m s^{-2} [C1]

Same vertical displacement for both proton and alpha

[C1]

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$t_{alpha} = 7.2 \times 10^{-8}$ s

Using $s_x = u_x t$, since u_x is the same for both, $(s_x)_{alpha} = 0.252\ m$

therefore alpha particle will exit the plates [A1]

4 (a) The heating effect is due to power dissipation in the coil which is dependent on the root-mean-square current and not on the average current. [C1]
The root mean square current is the value of the steady direct current that would dissipate heat at the same rate as the alternating current in a given resistor and it is non-zero. Hence, there is heating effect in the coil. [C1]

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

$V_s = 15 \times 16k = 240kV$ [M1]

$P_{loss} = I^2R$

$= \left(\frac{20 \times 10^6}{240 \times 10^3}\right)^2 \times 20 \times 10 = 1.39 \times 10^6 W$ [A1]

(ii) $P_{loss} = \left(\frac{20 \times 10^6}{16 \times 10^3}\right)^2 \times 20 \times 10 = 3.13 \times 10^8 W$

Energy saved
$= (3.13 \times 10^8 - 1.39 \times 10^6) \times 24 \div 1000$
$= 7.48 \times 10^6 kwh$
Amount saved $= 7.48 \times 10^6 \times 0.10$
$= \$7.48 \times 10^5$

5 (a) $R\cos 14° = W = 8500$

$\Rightarrow R = \frac{8500}{\cos 14°}$ B1

Horizontal component of R = $R\sin 14° = \frac{8500}{\cos 14°}\sin 14°$ B1

$= 2100$ N

(b) Horizontal component of R provides the centripetal force for circular motion.

$\Rightarrow m\frac{v^2}{r} = 2100$

$\Rightarrow \frac{8500 \times v^2}{9.81 \times 150} = 2100$ M1

$\Rightarrow v = 19$ m s^{-1} A1

(c) There is a greater centripetal force to be provided at higher velocity. Hence, there is a horizontal component of frictional force acting on the car besides the reaction force R, providing the centripetal force required for its circular motion M1
The car will tend to slide up the slope. A1

6 (a) (i) -When an electron transits from a higher energy level to lower energy level, **energy is released** as electromagnetic wave or in the form of a **photon, of energy hf**. The difference in energy between 2 levels, ΔE is equal to the energy of the photon/ or **ΔE = hf.** B1

-since energy level is discrete, the **difference in energy is also discrete**. Hence, only **certain discrete frequencies exist**, hence line spectra obtained. B1

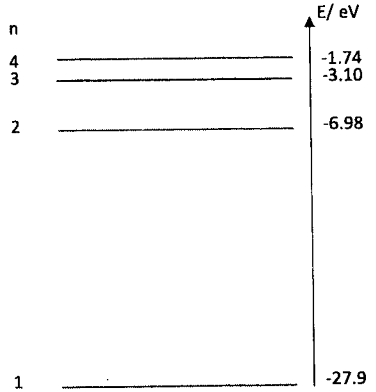
(ii) Energy has to be supplied to the electron to bring it to infinity/ to remove the electron, where PE is zero without a change in KE B1

OR

The electron is **bound** to the nucleus. Total energy of the system/atom is negative. Hence work has to be done to remove the electron from the atom.

(ii) Using $E_n = -\frac{27.9}{n^2}$

n	E_n / eV
1	–27.9
2	–6.98
3	–3.10
4	–1.74



All E values correct – B1

Relative spacing between energy levels correct – B1

Diagram must be fully labelled with n and E values – B1

(iii) Using $\Delta E = E_n - (-27.9) = 27.9 - \frac{27.9}{n^2}$, where ΔE represents the remaining energy of the colliding electron.

n	ΔE / eV
$1 \rightarrow 2$	20.92
$1 \rightarrow 3$	24.80
$1 \rightarrow 4$	26.16
$1 \rightarrow 5$	26.78

Calculation of ΔE for $1 \rightarrow 4$ **and $1 \rightarrow 5$**

Electron does not have enough energy to excite to n = 5 M1

Hence highest energy level reach is n = 4 A1

(iv) Using

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

Shortest wavelength

$$\lambda = \frac{hc}{\Delta E_{4\rightarrow 1}} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{26.16\times1.60\times10^{-19}} = 47.5 \text{ nm}$$ C1 A1

(b) (i) Maximum energy of electron is equal to energy of photon with shortest wavelength.

$$E_{max} = \frac{hc}{\lambda_{min}}$$ [C1] C1

Accelerating potential

$$V = \frac{hc}{e\lambda_{min}} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{1.60\times10^{-19}\times2.00\times10^{-10}}$$

$= 6220$ V A1

Note: λ_{min} must be read to **½ small square**, otherwise minus 1 mark

(ii) -Bombarding high energy electrons **knock out** the inner shell electrons of the target atoms. Hence, electrons transit from higher orbital shells to the vacant inner shells B1

-These transitions result in the emission of (X-ray) photons whose energies are given by the difference in the energy levels = $\frac{hc}{\lambda}$, resulting in sharp peaks at **specific** wavelengths of 4.00 x 10^{-10} m, 6.60 x 10^{-10} m and 9.95 x 10^{-10} m. B1

7 (a) (i) 1 By Newton's 3[rd] law, the rocket exerts a force on the gases so the gases exert an equal and opposite force on the rocket. B1

By Newton's 2[nd] law, this (net) force on the rocket will cause it to accelerate. B1

2 Total momentum of rocket and gas as a system remains constant since there is no (net) external force acting on it. B1

B1

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After engine is turned on, gases gain momentum to the left, rocket will gain equal magnitude of momentum to the right.

3 Force on gases = rate of change of momentum of gases
= Rv B1
So force on rocket = Rv B1
Hence $ma = Rv$ B1
$\Rightarrow a = \frac{Rv}{m}$ A0

(ii) After the fuel in the 1st stage is used up, the acceleration of the rocket will be higher since m decreases. M1
Hence, the 2 stage rocket will have a larger final speed. A1

(b) (i) 1 constant net force = weight of the girl = 350 N
mass of the girl $= \frac{350}{9.81}$ C1
$= 36$ kg A0

2 Time taken for the girl to fall before touching the trampoline = 0.50 s
$v = u + at$
$= 0 + 9.81(0.50)$
$= 4.91$ m s^{-1} A1

3 Maximum upward net force, F_{net} = 1400 N
$F_{net} = N - W$ C1
$N = F_{net} + W$ = 1400 + 350
= 1750 N A1

(ii) 1 The net force decreases as normal contact force increases. B1
Therefore, the acceleration decreases.
Speed increases at a decreasing rate. B1

At point D, the net force is zero, normal contact force equals weight and the girl has maximum speed. B1

2 change in momentum = area under graph from C to D
$= \frac{1}{2} \times 350 \times (0.53 - 0.50)$ C1
= 5.3 Ns A1

3 $m(v_D - v_C) = \Delta p$ e.c.f. from part (ii)2
$36(v_D - 4.9) = 5.0$ C1
v_D = 5.0 m s^{-1} A1

8 (a) (i) $F = \frac{1}{4\pi\varepsilon_0}\left(\frac{1.60 \times 10^{-19} \times 1.60 \times 10^{-19}}{(10^{-14})^2}\right)$ C1
$= 2.3$ N A1

(a) (ii) $\langle KE \rangle = \frac{3}{2}KT$
$70 \times 10^3 (1.60 \times 10^{-19}) = \frac{3}{2}(1.38 \times 10^{-23})T$ C1
$T = 5.4 \times 10^8$ K A1

(a) (iii) Some nuclei will be travelling faster / have greater kinetic energy to overcome electrostatic repulsion and hence cause fusion. B1

(a) (iv) $E = \Delta mc^2$
$18 \times 10^6 (1.60 \times 10^{-19}) = \Delta m (3.00 \times 10^8)^2$ C1
$\Delta m = 3.2 \times 10^{-29}$ kg A1

(b) (i) graph: smooth curve in correct direction starting at (0,0) M1
D at $2t_{½}$ is 1.5 times that at $t_{½}$ (± 2 mm) A1

(b) (ii) D = number of parent nuclei that decayed
=original number of parent nuclei – number of parent nuclei remaining at time t M1
$= N_0 - N$
$= N_0 - N_0 e^{-\lambda t}$
$= N_0 (1 - e^{-\lambda t})$

(b) (iii) 1. ${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + X\,{}^4_2He + Y\,{}^{0}_{-1}e$
238 = 206 +4X ⇒ X = 8 ∴8 alpha decays M1

92 = 82 + 2X – Y
92 = 82 + 2(8) – Y M1
Y = 6 ∴6 beta decays

(b) (iii) 2. $D = N_0(1 - e^{-\lambda t})$ OR $N = N_0 e^{-\lambda t}$
$\frac{D}{N_0} = 1 - e^{-\lambda t}$ OR $\frac{N}{N_0} = e^{-\frac{\ln 2}{t_{1/2}}t}$
$0.39 = e^{-\frac{\ln 2}{4.47 \times 10^9}t}$ OR $1 - 0.39 = e^{-\frac{\ln 2}{4.47 \times 10^9}t}$ C1
$t = 3.19 \times 10^9$ years OR $t = 3.19 \times 10^9$ years A1

(b) (iv) 1. $N = N_0 e^{-\lambda t}$
$N_0 = \frac{N}{e^{-\lambda t}}$ M1

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	$D = N_0 - N$ $= \frac{N}{e^{-\lambda t}} - N$ $= N\left(\frac{1}{e^{-\lambda t}} - 1\right)$	M1
(b) (iv) 2.	$D = N\left(\frac{1}{e^{-\lambda t}} - 1\right)$ $\frac{D}{N} = \left(\frac{1}{e^{-\frac{\ln 2}{\lambda}t}} - 1\right)$	C1
	$22.8 = \left(\frac{1}{e^{-\frac{\ln 2}{7.0\times10^{8}}t}} - 1\right)$ $t = 3.17 \times 10^9$ years	A1
(b) (iv) 3.	Any two from: • Allows the mean to be calculated • Some daughter product may have left the sample • (Use of three series) allows identification of anomalous results/series • Spread of results indicates uncertainty	B1 B1

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2022 TJC H2 Physics Preliminary Examination Paper 4 Mark Scheme

Suggested mark scheme for Question 1

No	Marking Instructions	Mark	Score
1(a)(i)	*r* measured to correct d.p. and unit, recorded to 2 or 3 sf (**r = 14.5 Ω m^{-1} range of *r* is within 10%)** **Do not accept use of V/I whether V is found from voltmeter or use 1.5V**	1	
(a)(ii)	zero error in 2 dp & **repeat** measurement of *x* (**x = 0.26 mm, range of x is with 10%)** *x* recorded to the 2 dp in mm or 3 dp in cm	1	
(a)(iii)	Substitutions and calculation of ρ correct with correct unit: **Ω m**	1	
(b)(i)	Substitutions and calculation of n correct with correct sf (2 or 3 sf). No unit for n	1	
(c)	Collected 6 or more sets of data (*c and I*). Award 0 mark if assistance was rendered, or collected only 5 sets of data. **Range of c ≥ 40.0 cm**	1	
	Each column heading must contain an appropriate quantity and unit	1	
	Consistency in no. of dp for raw readings (*c* to 1 dp in cm or 3 dp in m; *I* to 1 dp in mA; **c > d**)	1	
(d)(i)	Correct calculation of quantity $\frac{(n+2)}{(n+1)}$ and all calculated values given to appropriate no. of sf (3 sf)	1	
	Linearising equation and deriving gradient/y-intercept of graph	1	
	Appropriate scales – awkward scales (e.g. 3:10) are not allowed and scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Correct labelling of axes with correct units	1	
	All observations plotted to an accuracy of half a small square	1	
	Line of best fit – with a fair scatter of points on either side of the line	1	
	Gradient – hypotenuse of the triangle is greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Value of *S* determined correctly with correct unit	1	
	Y intercept – read off directly from the graph to half a small square or determined from $y = mx + c$ using a point on the line Value of *T* determined correctly with correct unit	1	
(d)(ii)	1. read off the value of *I* from the graph at $\frac{(n+2)}{(n+1)} = 2$ 2. set $c = d$, read off the value of *I* from the ammeter 3. Using the equation and values of *S* and *T*, calculate *I* when n = 0	1	
(e)	Straight line with smaller gradient and the same Y-intercept (The 2 graphs cannot cross each other)	1	
(f)	- Measure thickness of wire using micrometre screw gauge. Read from ammeter the maximum current I_{max} before *R* changes. - Vary by decreasing variable resistor/supply until resistance *R* changes, monitor R using ohmmeter. Repeat with further 5 wires of different thickness *t*. - Keep the material/resistivity and length of wire constant OR keep the temperature of the surrounding constant - Assume $I = kt^x$ → $\lg I = x \lg t + \lg k$ Plot graph of lg *I* against lg *t*, where *x* is gradient & lg *k* is vertical intercept -wires of very small thickness will have very large resistance. For the same increase in current, the thin wires get heated up faster so maximum current will be reached sooner, precision of maximum current is less/ high uncertainty in measurement of maximum current.	1 1 1 1 1	
	Total	21	

Suggested mark scheme for Question 2

No	Marking Instructions	Mark	Score
2(b) (i)	Value of raw θ to the nearest degree, with unit, in range θ < 90°.	1	
(ii)	Percentage uncertainty in θ based on **absolute uncertainty of 2 to 8°**, and correct method of calculation. If repeated readings have been taken, then the uncertainty can be half the range (but not zero) if the working is clearly shown.	1	
(iii)	Correct calculation of cos (θ / 2) correct to 2 s.f.	1	
(c) (ii)	Value of T_1 with unit and in range **0.4 s < T_1 < 1.2 s.**	1	
	Evidence of **repeated measurement** here or in (e)(ii) or (f)(ii).	1	
(d) (ii)	Value of T_2 with unit in range **0.6s < T2 < 1.4 s.**	1	
(e)(ii)	Second value of θ.	1	
	Second values of T_1 and T_2.	1	
	Second value of T_1 > first value of T_1 and Second value of T_2 < first value of T_2.	1	
(f) (i)	Two values of k calculated correctly.	1	
(ii)	Sensible comment relating to the calculated values of k, testing against a criterion specified by the candidate.	1	
	Total	11	

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Suggested mark scheme for Question 3

No	Marking Instructions	Mark	Score
1(a)(i)	*F* measured to 1 d.p. with unit. Evidence of repeated measurement.	1	
(a)(ii)	Correct explanation of the difficulty in the measurement. -reaches maximum force too suddenly or within a short time before reading can be taken/There is no notice of when the magnet is released before reading is taken.	1	
(a)(iii)	Correct calculation of percentage uncertainty expressed in 1 or 2 s.f. and uncertainty in *F* is 0.2 N – 0.6 N	1	
(b)(i)	Zero error in 2 or 3 dp in mm **& repeat** measurement of *t* **(range of *t* is within 10%)**. *t* recorded to 2 dp in mm or 3 dp in cm.	1	
(b)(ii)	Correct explanation of method to make measurement accurate. - Account for zero error; take repeated measurement in different positions/places of slides and find average.	1	
(b)(iii)	*F* measured to 1 d.p. with unit. Evidence of repeated measurement.	1	
(c)(i)	Collected 4 sets of data (*t and F*) with correct trend. Award 0 mark if assistance was rendered, or collected less than 4 sets of data.	1	
	Each column heading must contain an appropriate quantity and unit Consistency in no. of dp for *t* and *F*, correct s.f. for 1/*t*	1	
(c)(iii)	Appropriate scales – awkward scales (e.g. 3:10) are not allowed and scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Correct labelling of axes with correct units All observations plotted to an accuracy of half a small square	1	
	Line of best fit – with a fair scatter of points on either side of the line	1	
	Valid conclusion with the correct trend	1	
	Total	11	

Suggested Mark Scheme for Q4

Score	Mark	Marking Instructions
		Design (2 marks) labelled diagram of workable experiment including:
	A1	• tube supported • (loud)speaker **positioned in line with the tube** • signal generator connected to (loud)speaker
	A2	labelled microphone, **positioned outside tube in line with tube**, connected to labelled oscilloscope or correct circuit symbol if setup is unworkable- A1 and A2 = 0 mark
		Procedure (5 marks)
	B1	-Use vernier calipers to measure *d* **and** Use half metre rule/metre rule to measure *L*.
	B2	-Expt A: Method to vary *L* while keeping *d* constant to obtain 6 sets of data. Expt B: Method to vary *d* while keeping *L* constant to obtain 6 sets of data.
	B3	-Method to vary and measure *f*. Eg. increase frequency of signal generator until **first** maximum amplitude detected by microphone
	B4	-Method to determine period *T* from oscilloscope, e.g. no. of divisions × time-base, find *f* = 1 / *T*. -Control of variables:
	B5	Method to keep *d* constant (Expt A), Method to keep *L* constant (Expt B) **and either** Method to keep distance of speaker & microphone from each end of tube constant,- Method to keep temperature of surroundings constant
		Analysis (3 marks)
	C1	Expt A: vary *L*, constant *d* Plot graph of $\lg\left(\frac{1}{f}\right)$ against lg *L*: -Relationship is valid if a straight line is produced. -Gradient = *m*, y-intercept = $lg\,(kd^n)$ - lg *v*
	C2	Expt B: vary *d*, constant *L* Plot graph of $\lg\left(\frac{1}{f}\right)$ against lg *d*: -Relationship is valid if a straight line is produced. -Gradient = *n*, y-intercept = $lg\,(kL^m)$ - lg *v*
	C3	-Determine *k* and *v* from y-intercepts of both graphs.
		Safety consideration (1 mark)
	C4	wear ear defenders to prevent damage to hearing/to avoid loud sounds **or** use a low volume to prevent damage to hearing/to avoid loud sounds
		Detail (1 mark)
	D1	-method to determine *f* at maximum amplitude, e.g. increase frequency to *f*, then continue increasing frequency, and then decrease frequency until value of *f* determined. -repeat measurements of *d* and average in different directions/positions or along the tube to minimize random error -perform experiment in a quiet room -Do a preliminary experiment to find a suitable range of L or d to have an observable/measurable waveform on the CRO. -other good physics suggestions
	12	

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2022 TJC H2 Physics Preliminary Examination Paper 4 Suggested Solution

Suggested Solution to Question 1

1(a)(i) When length of wire, L = 1.000 m, resistance of wire, R = 14.5 Ω
r = R/L = 14.5 Ω m^{-1}

(a)(ii) zero error = 0.00 mm
x = ½ (0.26 + 0.26) = 0.26 mm

(a)(iii)
$$r = \frac{\rho}{A}$$
$$\rho = \frac{\pi}{4}x^2 r$$
$$= \frac{\pi}{4}(0.26\times10^{-3})^2(14.5)$$
$$= 7.7\times10^{-7}\,\Omega\,m$$

(b)(i)
$$n = \frac{c-d}{d} = \frac{60.0-50.0}{50.0} = 0.200$$

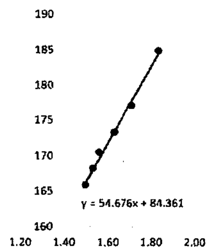
(c)

c /cm	n	$\frac{(n+2)}{(n+1)}$	I /mA
60.0	0.200	1.83	184.8
70.0	0.400	1.71	177.1
80.0	0.600	1.63	173.3
90.0	0.800	1.56	170.5
95.0	0.900	1.53	168.2
100.0	1.00	1.50	165.9

(d)(i) Plot a graph of I against $\frac{(n+2)}{(n+1)}$

$$S = gradient = \frac{184.0-165.6}{1.82-1.49} = \frac{18.4}{0.33} = 55.8\ mA$$

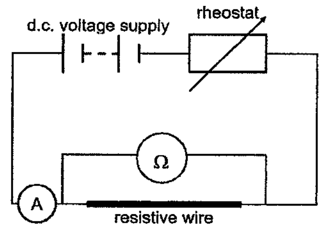
$sub\ (1.82, 184.0)\ into\ equation,$
$$184.0 = (55.8)(1.82) + T$$
$$T = 82.4\ mA$$



(d)(ii) Either method:
1. Use the graph, read off the value of I at $\frac{(n+2)}{(n+1)} = 2$
2. Use the circuit, set $c = d$, read off the value of I from the ammeter
3. Use the equation and substitute the values of S and T and n = 0, calculate I

(e) Since S is inversely proportional to d, a larger value of d will mean a smaller value of S, while T is unchanged.
W is a straight line with smaller gradient with the same Y-intercept.

(f)



1. Measure thickness of wire using micrometre screw gauge.
2. Start at maximum resistance then slowly decrease variable resistor/supply while monitoring the resistance, R of the wire using an ohmmeter until resistance R changes. Read from ammeter the maximum current I_{max} before R changes. (Repeat to find average I_{max}) Repeat step 1 and 2 with further 5 wires of different thickness t.
3. Keep the material/resistivity and length of wire constant OR keep the temperature of the surrounding constant by conducting the experiment in a temperature-controlled room.
4. To investigate how I depends on t, assume the relationship $I = kt^x$
→ $\lg I = x \lg t + \lg k$
Plot graph of lg I against lg t, to get a straight line where x is gradient & lg k is vertical intercept

-wires of very small thickness will have very large resistance. For the same increase in current, the thin wires get heated up faster so maximum current will be reached sooner, precision of maximum current is less/ high uncertainty in measurement of maximum current.

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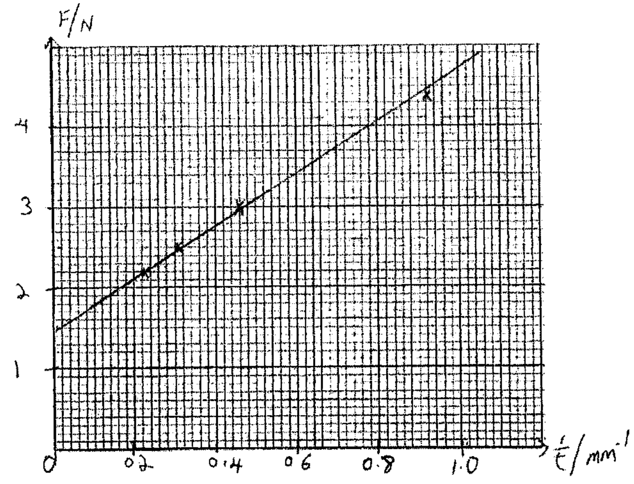
Suggested Solution to Question 2

2	(b) (i)	θ = 56°
	(b) (ii)	Percentage uncertainty = 5/56 × 100% = 8.9%
	(b) (iii)	cos (θ / 2) = 0.88
	(c) (ii)	T_1 = ½(16.2/20+16.1/20) = 0.808 s
	(d) (ii)	T_2 = ½(11.6/12+9.8/9) = 1.03 s
	(e) (ii)	θ = 37°
		T_1 = ½(12.5/15+16.6/20) = 0.832 s T_2 = ½(14.5/16+14.5/16) = 0.906s
		Second value of T_1 > first value of T_1 and Second value of T_2 < first value of T_2.
	(f) (i)	When θ = 56° k = (0.808/1.03 cos 28°) = 0.888 When θ = 37° k = (0.832/0.906 cos 18.5°) = 0.968
	(iii)	% difference in k = (0.968-0.888)/0.888 × 100% = 9% Since % difference is larger than % uncertainty calculated in (bii), results do not support the relationship.

Suggested Solution to Question 3

3(a)(i)	F_1 = 7.0 N, F_2 = 6.8 N, <F> = 6.9 N
(a)(ii)	It reaches maximum force too suddenly or within a short time before reading can be taken / Maximum force reading is present for only a very short time.
(a)(iii)	%uncertainty= $\frac{\Delta F}{F}\times 100\% = \frac{0.2}{6.9}\times 100\% = 2.9\%$
(b)(i)	zero error = 0.00 mm t = ½ (4.34 + 4.38) = 4.36 mm
(b)(ii)	Account for zero error; take repeated measurement in different positions/places of slides and find average.
(b)(iii)	F_1 = 2.4 N, F_2 = 2.6 N, <F> = 2.5 N
(c)(i)	(see table below)
(c)(ii)	Plot a graph of F against $1/t$

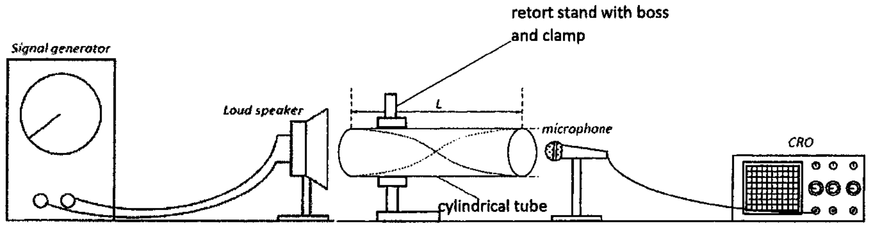
No. of slides	t /mm	Maximum force/ N F_1	F_2	<F>	$1/t$ / mm^{-1}
4	4.36	2.1	2.3	2.2	0.229
3	3.27	2.6	2.4	2.5	0.306
2	2.18	3.1	2.9	3.0	0.459
1	1.09	4.6	4.2	4.4	0.917



Since a straight line graph is obtained, it shows that F is linearly related to $1/t$
From graph, gradient = p and y-intercept = q

Suggested solution for Q4:

Diagram



Defining the problem

Independent variables: Expt A: length L; Expt B: diameter d

Dependent variable: frequency f of sound

Control of variables: Expt A: diameter d; Expt B: length L

Keep distance of loud speaker & microphone from each end of tube constant by fixing their position on stands, measure and monitor distance using half-metre rule/ metre rule.

Keep temperature of surroundings constant by conducting experiment in a temperature controlled room and monitor with thermometer.

Method of data collection

Expt A: vary L, constant d

1. Set up the rest of the apparatus as shown. Both the loud speaker and microphone *should* be positioned outside the tube and aligned along the axis of the cylindrical tube. They should be as close to the tube as possible without touching it.
2. Measure the diameter d of the cylindrical tube using vernier calipers and its length L using a half-metre rule/ metre rule.
3. Starting from zero, increase the frequency of the sound produced by the loudspeaker gradually by adjusting the frequency settings of the signal generator until the amplitude of sound detected on the CRO display **first** reaches a <u>maximum</u>.
4. Determine T, the time for 1 complete waveform by calculating no. of divisions × time-base settings of the CRO. Calculate the frequency f of the sound using $f = 1/T$.
5. Repeat steps 1 to 4 using cylindrical tubes of different lengths L but the same diameter d until 6 sets of readings for L and f are obtained.

Expt B: vary d, constant L

1. Repeat steps 1 to 4 using 6 cylindrical tubes of the same length L but different diameter d to obtain 6 sets of readings for d and f.

Method of analysis

Given $\frac{v}{f} = kL^m d^n$

<u>Expt A</u>

vary L, constant d. $\frac{v}{f} = (kd^n)L^m \Rightarrow \lg v + \lg\left(\frac{1}{f}\right) = m\lg L + \lg(kd^n)$

Plot graph of $\lg\left(\frac{1}{f}\right)$ against lg L

Relationship is valid if a straight line is produced.

Gradient = m, y-intercept = $\lg(kd^n) - \lg v$

<u>Expt B</u>

vary d, constant L. $\frac{v}{f} = (kL^m)d^n \Rightarrow \lg v + \lg\left(\frac{1}{f}\right) = n\lg d + \lg(kL^m)$

Plot graph of $\lg\left(\frac{1}{f}\right)$ against lg d

Relationship is valid if a straight line is produced.

Gradient = n, y-intercept = $\lg(kL^m) - \lg v$

Determine k and v from y-intercepts of both graphs.

Safety consideration

wear ear defenders to prevent damage to hearing/to avoid loud sounds

or

use a low volume to prevent damage to hearing/to avoid loud sounds

Additional details

1. method to determine f at maximum amplitude, e.g. increase frequency to f, then continue increasing frequency, and then decrease frequency until value of f determined.
2. repeat measurements of d and average in different directions/positions or along the tube to minimize random error.
3. perform experiment in a quiet room
4. Do a preliminary experiment to find a suitable range of L or d to have an observable/measurable waveform on the CRO.

Note:
Do a preliminary experiment to find a suitable range of L and d for measurable f (is not applicable in this experiment because the CRO can measure all f)

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